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DISTRIBUTION OF HEAVY ELEMENTS HAZARDOUS TO HEALTH, ALINAS VALLEY REGION, CALIFORNIA

1980

LIFORNIA DIVISION OF MINES AND GEOLOGY

CIAL REPORT 138

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Special Report 138

DISTRIBUTION OF HEAVY ELEMENTS HAZARDOUS TO HEALTH, SALINAS VALLEY REGION, CALIFORNIA

By
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Geochemist

1980

CALIFORNIA DIVISION OF MINES AND GEOLOGY
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ABSTRACT

Samples of stream sediment and bedrock from the Salinas Valley region were analyzed to determine the distribution and the amounts of potentially health–hazardous heavy elements (arsenic, cadmium, copper, lead, mercury, and zinc). Cadmium was found to be anomalously high in the stream sediments and soils in the King City–San Ardo area in the extreme southeast corner of the project area. The California Department of Agriculture obtained similar high–cadmium values in samples of agricultural soils from the same area. The stream sediments appear to be derived from Middle Miocene marine strata exposed in the drainage basin. The source of the anomalous cadmium in these stream sediments in the King City–San Ardo area was traced to relatively thin beds of phosphatic rocks. Cadmium might exist in the phosphatic rocks elsewhere in the United States, and, because of the potential health hazard from cadmium, these other phosphatic rocks should be evaluated for possible cadmium contamination.

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DISTRIBUTION OF HEAVY ELEMENTS HAZARDOUS TO HEALTH, SALINAS VALLEY REGION, CALIFORNIA

By Hasmukhrai H. Majmundar[1]

INTRODUCTION

n July 1971, Governor Ronald Reagan mandated an intera- cy public health project to determine the sources and distri- ion of certain health–affecting elements in the Salinas Valley. ticipating in the study were a number of organizations repre- ting State, local, and federal agencies and also the private or. The project was coordinated by the Project Committee of Monterey Basin Pilot Monitoring Project, composed of rep- ntatives of each of the participating State and local agencies. project objective was to design an efficient and effective nitoring program for tracing the source, movement and fate nvironmentally harmful substances, and to determine the nt to which such a program could be planned and imple- nted by a multitude of agencies with separate interests and onsibilities with regard to environmental quality.

he report presents the results of the California Division of nes and Geology participation in the project. The Division's t in the project included (1) the development of accurate niques for sampling the stream sediments of the project area; the development of analytical procedures for detecting very ll concentrations of arsenic, cadmium, and mercury; and (3) preparation of maps showing the distribution of arsenic, mium, copper, lead, mercury, and zinc in the sediments of nas Valley. These elements were selected for study because heir health–hazard characteristics.

ertain compounds of arsenic are poisonous when eaten in e than trace amounts, but little is known about their other racteristics, including their carcinogenic potential. Neverthe- , arsenic is generally well known to be an undesirable element n a health standpoint. Throughout the world arsenic is most ndant in areas in which sulfide deposit occurs.

admium is a known cause of high blood pressure and has identified as an extremely carcinogenic element (as has el). In its primary occurrence in nature, cadmium generally ssociated as a trace impurity with lead–zinc sulfide mineral mblages, and it can be expected to abound in areas contain- such minerals. The phosphatic sediments in the Middle Mio- unit of the project area are known to contain zinc; and, as ected, the presence of cadmium in these phosphatic sedi- ts was later confirmed by Project data.

Cadmium may be introduced into the environment by such industrial discharges as mine wastewater, smelter or refining exhausts, or electroplating wastes. It is also introduced when fertilizers containing phosphate rock are added to agricultural soils; such phosphate fertilizers contain 9 to 36 ppm Cd, which is absorbed in some grains and vegetables to the extent of 1 to 4 milligrams per hundred grams (mg/100g) (Furst and Haro, 1969). Superphosphate, another form of commercial fertilizer, can also be a source of cadmium in certain vegetables (Schroeder and Balassa, 1963).

Although the uptake of cadmium in plants is species dependent and certain crops can accumulate it much more readily than others, in general cadmium is retained in plants at concentrations ten times greater than those in animals. Older animals, however, because of the longer duration of their exposure, can have higher levels of concentration than plants. Strangely enough, children retain higher concentrations than adults.

The Monterey Basin Pilot Monitoring Project discovered that, in certain sections of the project area, elevated levels of cadmium are present in aquatic life as well as in terrestrial soils, plants, and animals. Filter–feeding organisms and scavengers living in the sediments were found to have the highest cadmium values.

Human beings can be exposed to cadmium via food, water, and air. Of these, however, exposure through food is by far the most significant. In uncontaminated areas, most foodstuffs contain less than 0.05 μg Cd/g wet weight, and the average daily intake probably is about 50 μg. Liver and kidney probably have concentrations larger than 0.05 μg/g. When foodstuff is contaminated by cadmium in soil and water, the cadmium concentrations may increase considerably. In water, the normal concentration of cadmium is less than 1 ng/g. If the cadmium concentration in drinking water exceeds 5 ng/g, it contributes a significant amount in daily uptake of cadmium. The normal concentration of cadmium in air is about 0.001 μg/m^3. In areas where cadmium–emitting factories are situated, average cadmium concentrations of 0.1 to 0.5 μg/m^3 have been recorded, which may result in the inhalation of 2 to 10 μg cadmium per day. Smoking also contributes to daily intake. Smoking one pack of cigarettes contributes 2 to 4 μg/d intake. (Friberg and others, 1971; Sandstead and others, 1974).

Table 1 gives the effects of anomalous levels of cadmium on animals and plants. Environmental cadmium poisoning has been

---

fornia Division of Mines and Geology, San Francisco, CA

*Table 1. Effects of anomalous levels of cadmium.**

Environmental Level	*Effects on Plants*		*Effects on Animals Other than Man*		*Effects on Man*	
	Established	*Conjectured*	*Established*	*Conjectured*	*Established*	*Conjectur*
Low	Absorbed through plant roots	–	–	–	–	–
High	–	Toxic	Acute: Testicular hemorrhage, male sterility. Chronic; hypertension. Little transfer to cow's milk from oral dose	Interferes with utililzation of Zn, Fe, and Cu. (Se prevents Cd–induced pregnancy toxemia.)	–	Hypertensio Competes w Zn at metallothion binding site kidney. Regi differences i human kidn (Japan and United State have higher levels).

*After Hopps, H.C. (1974).

established as the cause of an estimated 100 human deaths in Japan by itai–itai disease. Table 2 gives the predicted concentrations of cadmium in soils, municipal drinking water, and vegetables. The median values probably represent ordinary, adequate levels of cadmium in water, soils, and foods (Sandstead and others, 1974).

*Table 2. Predicted concentration of cadmium.**

	Median	*Range*
Soils, ppm	0.06	0.01 – 0.7
Finished Municipal Water, ppb	~1.0	< 1.0 – 10
Forge Grasses, ppm	0.37	0.03 – 2.4
Forge Legumes, ppm	0.04	0.04 – 0.05
Vegetables and Fruits, ppm	0.10	0.01 – 0.96

*Credited to Helen L. Cannon
By Hopps, H.C., 1974.

Copper and zinc, when ingested in the presence of each other, can be toxic in varying degrees to fish and to humans.

The high toxicity of lead has long been known. The hazard from naturally occurring lead is small compared to that of man–created lead contamination, mostly from tetraethyl lead gasoline.

Mercury is highly toxic and has been identified as a carcinogen (Furst and Haro, 1969). It concentrates in body tissues with age and has been the source of area–wide health problems. Mercury tends to concentrate in the internal body organs of animals (liver, kidneys), and in plants. The U.S. Geological Survey investigated mercury in air, water, soil, and rock, and its effect on man (Fleishcher, and others, 1970). Most of the earth's crust contains little mercury (80 ppb Hg), but large amounts of mercury are generally present in areas in which any type of su
deposit occurs. Mercury enters the atmosphere throug
natural disintegration and decomposition of mercury–be
minerals. Mercury is removed from the atmosphere by ra
and by absorption in particulate matter. The particulate m
may be temporarily suspended in streams or lakes, but it
to settle to the bottom eventually.

The Division's study provides background data on the na
distribution of these six elements in the project area and c
used as a base level against which other participants in the
project can monitor air, water, particulate matter suspend
air and water, agricultural soils, vegetables, milk, hospital
and industrial discharges in Monterey County.

The California Department of Water Resources include
ron among the elements tested in their analyses of stream
samples during the project. However, Boron could n
analyzed for lack of a sensitive analytical procedure to me
its presence in stream sediment samples.

As indicated by analyses of the stream sediments, a hig
portion of cadmium is present in sediments and soils near
City and San Ardo. An effort was made to trace the sou
this cadmium by collecting bedrock samples from this area
bedrock samples also were analyzed for arsenic, cadmium
per, lead, mercury, and zinc. The proportion of cadmiu
found to be high in some of the phosphatic beds. Therefo
the bedrock samples containing more than 10 ppm Cd also
analyzed for phosphorus in order to determine the corre
between the two. It was established that there is a very
correlation between these two elements; when one elem
higher, the other seems to be higher.

GEOLOGY

The geological framework of the project area is describ
Hart (1966) and Durham (1964, 1966, and 1970) and s
on open–file maps by Dibblee (1967, 1968, 1969, 1971 and 1
and the Geologic Map of California (Jennings and Strand,
Jennings, 1958). The Salinas River drainage area extends

miles southeast of this project area (Figure 1), but the main nations in the project area are pre–Cretaceous metamorphic cks, Upper Cretaceous granitic intrusive rocks, and Tertiary Pleistocene marine and nonmarine sedimentary rocks.

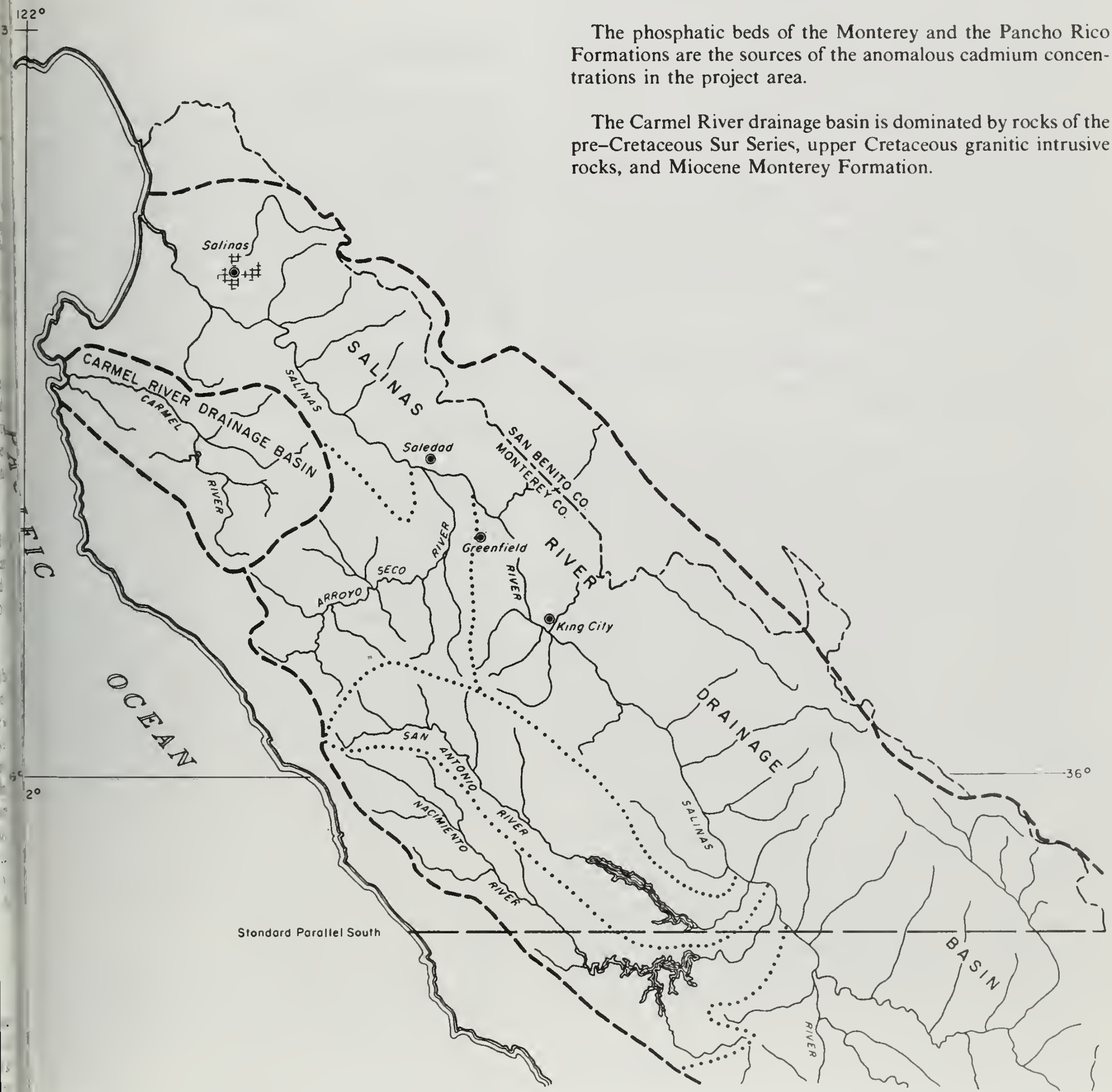
he pre–Cretaceous rocks are known as the Sur Series and sist of crystalline limestone and dolomite, quartzite, schist, iss, and various contact metamorphic rocks. They are the st rocks of the project area and are located on the segment e west flank of the Salinas Valley that lies roughly between dad and Salinas.

pper Cretaceous granitic rocks are predominant in the Gabi- Range on the northeast flank of the Salinas Valley, extending hly from King City past Salinas.

The Tertiary and Plio–Pleistocene units occupy the southern two–thirds of the project area on both flanks of the Salinas Valley and the San Antonio and Nacimiento River drainage basins. The predominant Tertiary unit is the Miocene Monterey Formation, consisting mainly of siliceous and clayey shale and sandstone beds. In the Monterey Formation, phosphatic beds and petroliferous clay shale occur separately in various localities. The Monterey rocks and minor Plio–Pleistocene Paso Robles continental sandstone, conglomerate, and clay occur mainly in the southwest part of the project area — on the west flank of the Salinas Valley and in the basins of the San Antonio and Nacimiento Rivers. The principal Pliocene unit is the marine Pancho Rico Formation, consisting mainly of diatomaceous mudstone and siltstone. The Pancho Rico and the Paso Robles Formations are exposed along the east flank of the Salinas Valley from about the latitude of Greenfield to the south edge of the project area.

The phosphatic beds of the Monterey and the Pancho Rico Formations are the sources of the anomalous cadmium concentrations in the project area.

The Carmel River drainage basin is dominated by rocks of the pre–Cretaceous Sur Series, upper Cretaceous granitic intrusive rocks, and Miocene Monterey Formation.



ure 1. Index map of drainage basins in Salinas Valley.

DEVELOPMENT OF SAMPLING AND ANALYTICAL PROCEDURES

Sampling Techniques

Sampling for the first part of the project was restricted to stream sediments of the drainage basins of the Salinas and Carmel Rivers. Samples were collected from most of the streams in the area (Figure 2). A few samples were taken from ephemeral streambeds in canyons which are dry in the summer. The soil and sediment in several of the canyons have been disturbed during cultivation of barley for cattle feed, making it difficult to obtain reliable, undisturbed samples. Streams generally were found to be excellent in terms of convenience and reliability for collecting samples. A total of 201 samples of stream sediment were collected. Locations of these samples are given in Appendix A and shown on Figure 2. Locations of samples 572–576 and 593 are included on Figure 3, as they were collected south of the project area, near San Miguel and Bradley.

Sites for stream sediment sampling were spaced evenly over the project area and were selected as representative of the tributary streams. Composite samples were taken at each locality to represent the upstream drainage area. Figure 4 illustrates the pattern used: a tablespoon of the surficial sediment was collected at each of the sample points, spaced about 12½ feet apart by pacing, and put in a sample bag. Large pebbles and organic debris were discarded immediately.

Usually, 650–800 grams of sediment, representing 100 to 150 individual sample points, were collected; resulting composite sample was treated as a unit.

The size of the area sampled in this manner depended upon the local width of the stream beds, which ranged from about 20 feet to hundreds of feet. This method was devised to decrease the geochemical variability that might otherwise occur in a sample collected from a single point. The samples generally were collected from the active channel between the stream's terraces in both the wet and seasonally dry parts of the channel. Where this was not possible—for instance, in the deep water channels of the Salinas and Carmel Rivers—samples were collected from the stream deposits adjacent to the deep water. In areas under cultivation, the courses of intermittent streams could be traced by the fresh green color of the barley or grass and sampled accordingly. The sediment or, where necessary, the surface soil was collected along the trace of the stream path, and a composite sample was made.

A similar composite sampling technique was applied in collecting bedrock samples. From each rock formation, at each location, rock chips were collected at intervals of one to two feet over the entire exposure. A composite sample was made by crushing all of the chips. Thus, each composite sample provided a representative sample of the exposed portion of each formation. A total of 259 composite bedrock samples were collected. (Figure 3 and Appendix B). At some locations, samples were collected from a depth as great as two feet, as well as from the surface, in order to check the vertical variability.

Computer programs (Appendix I) were used for preparation of the sample identification list, tables of chemical analyses, and for storage and retrieval of chemical analyses.

Sample Preparation

The organic contents of each stream sediment sample, su dried leaves, grass, bark, rootlets, and other foreign objects, removed by handpicking, using a magnifying lens. Wet sa were dried under infrared heat lamps; all other samples air–dried. After the samples were sieved and all material l than 18–mesh was discarded, the minus 18–mesh fractio split (using a Jones splitter) until a representative porti 120–130 grams was obtained. This was pulverized (usi Braun pulverizer) and used for chemical analysis.

Bedrock samples were similarly crushed, pulverized, and for chemical analysis.

Digestion

STREAM SEDIMENT SAMPLES

Two separate digestion techniques were employed for st sediment samples: one for arsenic, cadmium, copper, lead, cury and zinc; the other especially for cadmium. Samples taining less than 2.5 ppm Cd could not be determined v digested by the total digestion technique which requires a tion factor of 25, while the detection limit for Cd is 0.1 pp solution. This would make it impossible to detect the very concentrations of cadmium present in some of the sam Therefore, a special digestion technique was used on the po of the split to be analyzed for cadmium. Both techniques described in detail in Appendix D.

For the minimum concentrations of element that can be m ured, see footnotes under Appendices F and G.

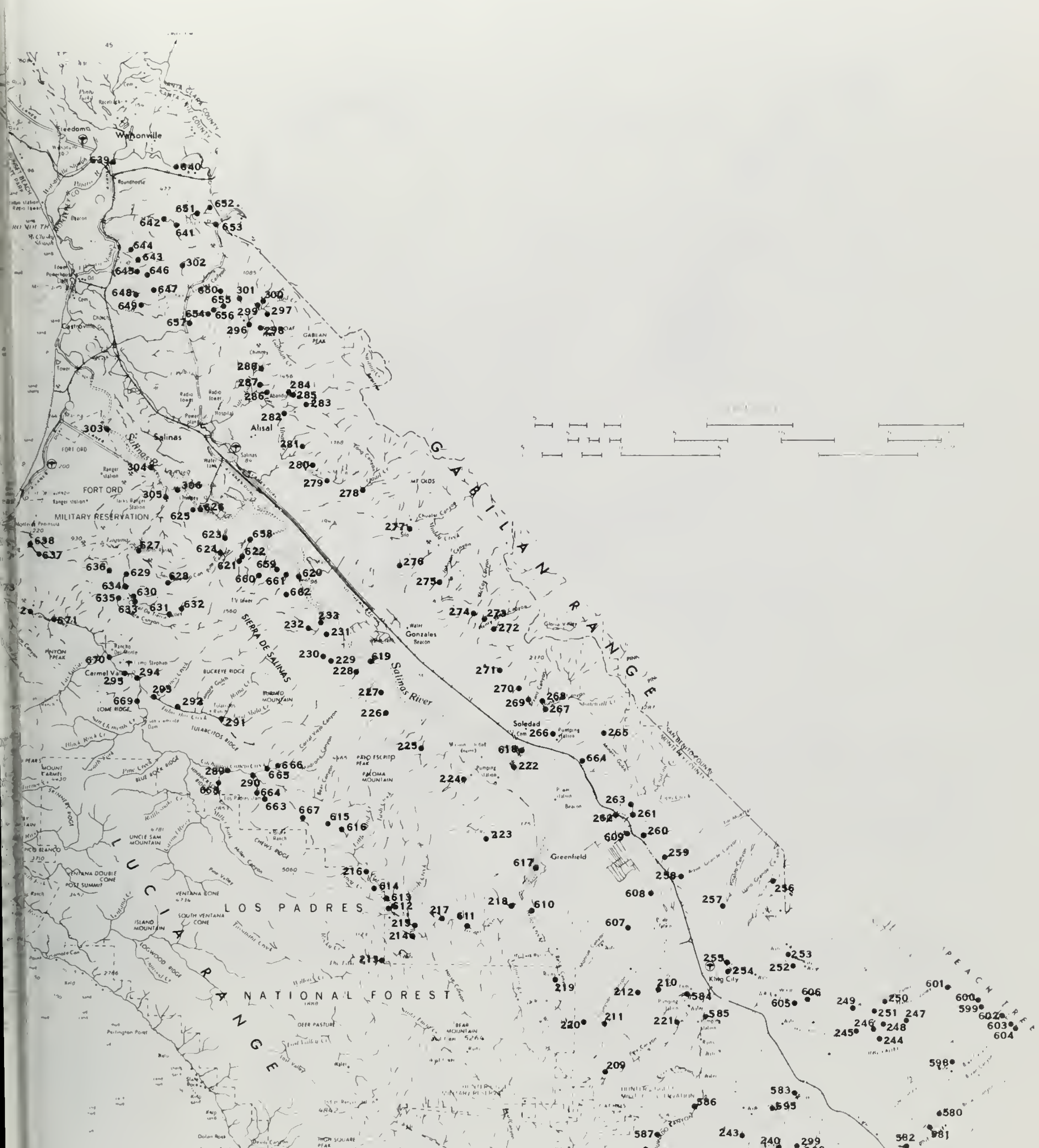
BEDROCK SAMPLES

Bedrock samples with a high concentration of phospho created a special problem when digested by the total diges technique. A white complex compound was produced w adhered to the glass walls of the apparatus and could no removed easily, particularly from the inaccessible, thin, and row closed tube of the modified soxhlet extractor. The com compound would sublime when heated but would condens the same wall when cooled. Because of this contamination p lem the extractor could not be reused, so another digestion t nique was developed (see Appendix D). Also, there was s doubt as to whether or not the cadmium salts from the bed samples were completely dissolved by use of the cold acid ext tion technique, which worked so satisfactorily for the str sediments. Thus, various techniques were developed and te to digest bedrock samples. Details of these techniques are given in Appendix D.

Analytical Techniques

MERCURY

For purposes of pollution control or toxicity monitor many analytical techniques are used to analyze for mercur various types of samples. Atomic absorption spectrophotom is excellent for use in trace element determination, but the t nique lacks the sensitivity to measure mercury in the parts- billion range. The flameless technique of atomic absorption used here, which gave a detection limit of 0.1 ppb Hg.



ure Index map of locations of stream sediment samples, Salinas Valley.

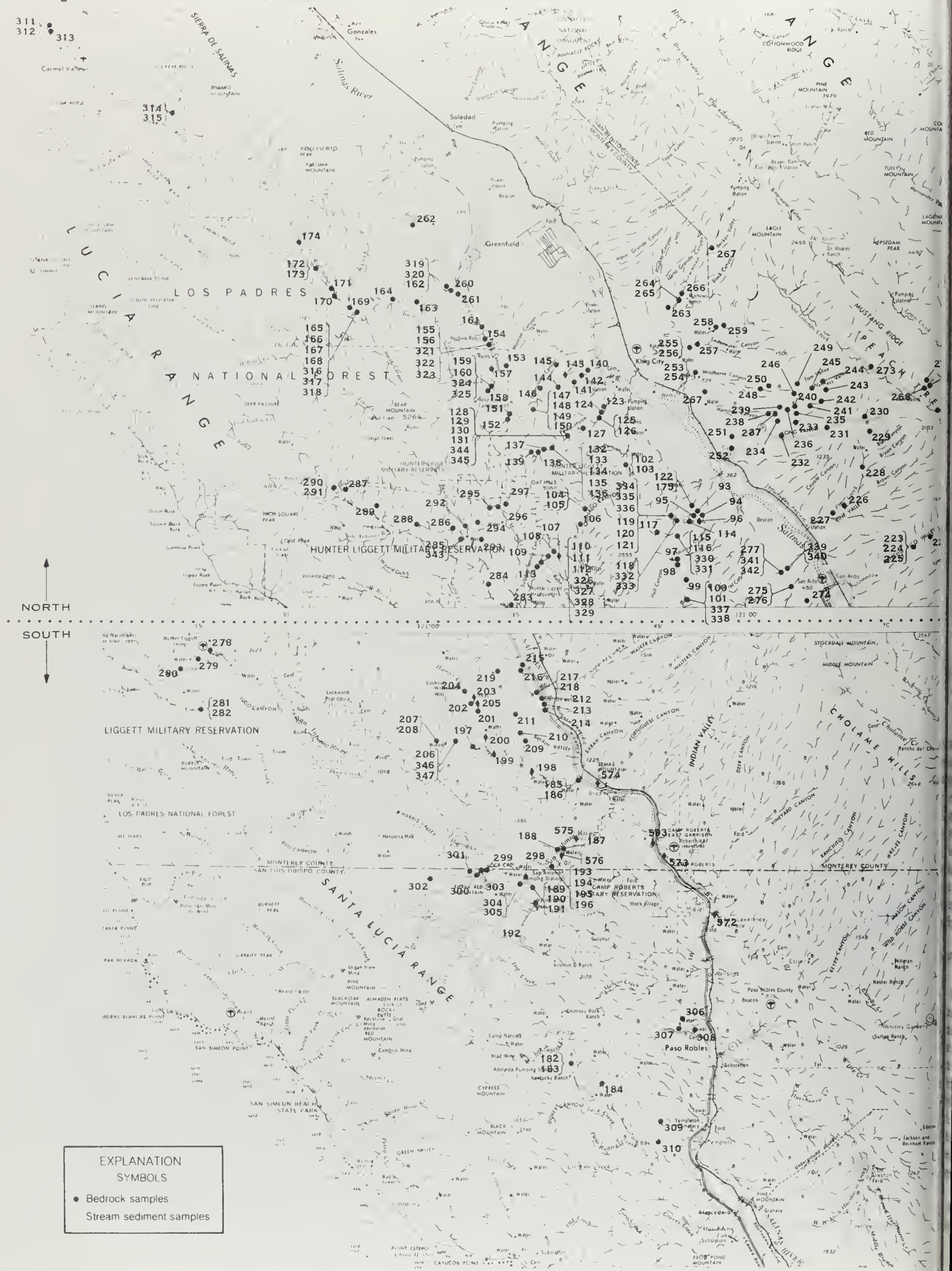


Figure 3. Index map of locations of bedrock and some stream sediment samples from Salinas Valley.

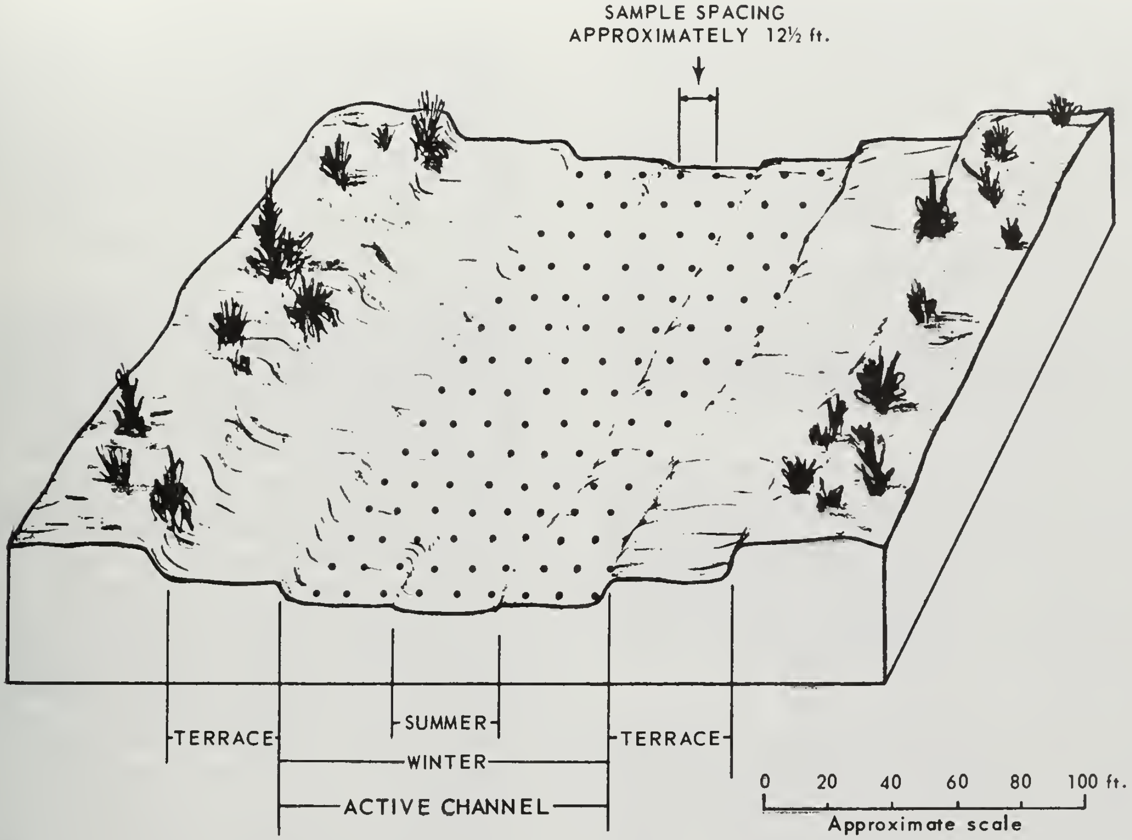


Figure 4. Technique for collecting composite stream sediments samples.

he mercury salts in digested samples were reduced to elental mercury by the addition of stannous chloride to the aple solution in a reaction vessel equipped with a magnetic tier. The mercury vapor thus released was transported by etion through a drying column to an absorption cell. The brption cell replaced the conventional burner in the optical a of the atomic absorption spectrophotometer. The absorpio was measured at the 2537 Å Hg wavelength and plotted on cart recorder. Mercury standards were measured and recordd imilarly. The concentration of mercury in the samples was ermined by relating the peak heights of those of the standards. eils of this technique are described in Appendix E.

ENIC

rsenic presents certain analytical problems which make its etmination difficult. The commonly used air–acetylene flame ar ot be used because arsenic reasonance lines lie in the far lt–violet region, where flame absorption is a problem. With ni flame, which creates a high background, there is a strong gl absorption and the available energy striking and photomulp r is reduced. If an argon–hydrogen flame is used instead of ne air–acetyline flame, these problems are considerably reucd. A danger of the argon–hydrogen flame is that it is colorss and an operator may touch the burner when the unit is in pation.

I the technique used, arsine gas was produced by reduction it hydrogen generated by the addition of zinc to hydrochloric acid. This arsine gas was collected in a rubber balloon, along with excess hydrogen and hydrogen sulfide gas if sulfide minerals were present in the sample. The arsine gas was carried away and introduced into the flame by means of an argon carrier gas. This technique gave very good sensitivity, allowing the detection of arsenic at submicrogram levels. By releasing the original sample matrix, interelemental interferences in the flame also were minimized.

The sample digests which were used for mercury determination also were used for arsenic determination after removing the suspended particles by filtering. The only difficulty with these digests is that they contain a considerable amount of nitric acid, which prevents the production of arsine. Nitric acid was, therefore, completely removed from these sample digests by slowly heating them with concentrated sulfuric acid.

Details of the adopted procedure are given in Appendix E.

CADMIUM, COPPER, LEAD, AND ZINC

Cadmium, copper, lead and zinc were determined by routine atomic absorption analytical procedures by direct aspiration of the sample digests.

PHOSPHORUS

Phosphorus was determined with the x-ray spectrometer by mixing one gram of 230-mesh sample with one gram of Whatman CF–11 cellulose powder, making pellets in Spex caps, and analyzing with an EDDT crystal and Cr target x-ray tube (Appendix E). All phosphorus results are corrected for the presence of high calcium.

RESULTS OF ANALYSES

Mercury

The general level of mercury in both stream sediments and bedrocks is lower than Taylor (1964) reports in the earth's crust (80 parts per billion); in bedrock samples, however, its level is about the same as in soils.

Only six stream sediment samples contained anomalous amounts (>65 ppb Hg) of mercury. The largest mercury concentration was 512 ppb Hg in Thompson Canyon, apparently from middle Miocene Monterey rocks. Five other samples contained 75–88 ppb Hg; three from streams draining an area of Pleistocene nonmarine sediments, and two from San Lorenzo Creek, which drains an area of Middle and/or Lower Pliocene marine sedimentary rocks and Holocene alluvium.

The threshold level—the transition point between normal (lognormal, here) and anomalous concentration—of mercury is 64.5 ppb Hg in stream sediment samples and 50 ppb Hg in bedrock samples. The cumulative frequency distribution for mercury for stream sediments is lognormal, while the bedrock samples show the presence of two separate populations with the anomalous population being 35 percent of the total analyzed samples.

Arsenic

Arsenic in the stream sediments seems to be at levels generally found in the earth's crust (Taylor, 1964), but lower than levels generally found in soils (Vinogradov, 1959). Arsenic appears to be present in the bedrocks at considerably higher levels than generally found in crustal rocks, but at approximately the same levels generally found in soils. The threshold levels of arsenic in the stream sediments is 9.25 ppm, and only three samples (1.5 percent of total collected samples) exceed this upper limit. From their locations near the south end of the project area, these three samples seem to have been derived from the rocks of the Middle Miocene marine Monterey Formation. In general, the samples collected from the southeast portion of the project area (the source apparently being the same rocks) show higher concentrations of arsenic than the samples collected from other parts of the area.

The threshold levels of arsenic in bedrocks is 38 ppm, and only eight samples (three percent of total collected samples) appear to exceed this upper limit. The distribution seems to be lognormal in both stream sediments and bedrocks. Samples of clay seams have unusually high amounts of arsenic.

In the project area, arsenic compounds are used as a chicken feed supplement to increase their growth rate, and chicken droppings are widely used as a fertilizer. No connection was established in this study between this possible source of arsenic and the anomalous arsenic values. Overall, arsenic is not abundant enough to be a health hazard in the project area.

Cadmium

In Monterey County, some stream sediment samples s
higher concentrations of cadmium than the general world–
concentration in the crust (0.2 ppm; Taylor, 1964) or in the
(0.5 ppm; Vinogradov, 1959). In general, the stream sedir
samples collected from southwest and southeast of King
and San Ardo contain anomalously large amounts (1.5 ppm
cadmium. Stream sediment samples from that same area are
high in arsenic and zinc. The source of these sediments appa
ly is the Middle Miocene marine rocks.

The California Department of Agriculture and the Unive
of California at Davis, Department of Environmental Toxic
gy ran a special sampling program in the Greenfield–King C
San Ardo area to determine the cadmium contents of agr
tural soils and the plants growing on them. Their results, f
140 collected samples, show that Lockwood Loam soil, as
as the vegetation associated with it, contains greater amoun
cadmium than other soils and their associated vegetation. S
ach and other leafy vegetables appear to carry higher cadm
contents than citrus fruits; grapes, in particular, contained n
mal amounts of cadmium. Lockwood Loam soil has been for
from older alluvial fans derived from the same general vic
in the southeast part of the project area in which sediments
high concentrations of cadmium. The results of the study
ducted by California Division of Mines and Geology perso
therefore, correlate positively with results of studies mad
personnel of the California Department of Agriculture anc
University of California at Davis Department of Environm
Toxicology. In addition to surface samples, the Departme
Environmental Toxicology took several cores of agricul
soils from this area to depths of six feet, and found that cadm
concentration is generally high and uniform throughout the
foot depth. This indicates that cadmium's presence is not d
the addition of fertilizer to the surface soils.

The background calculated for a perfect frequency dist
tion curve corresponds to the mode and median values and i
geometric mean of the results (Lepeltier, 1969). This geom
mean is a more significant value than the arithmetic mean.
also a more stable statistic, and less subject to change wit
addition of new data and less affected by high values. The re
for cadmium in bedrocks illustrate this. A high concentratio
cadmium in some of the bedrock samples produces the aritl
tic mean of 27.2 ppm Cd, which is higher than the threshold
of 15 ppm Cd. The geometric mean, however, which is 5.2
Cd, is not affected by the very high cadmium content of s
of the samples. The concentrations of cadmium in bedrock
ples is higher than crustal or soil abundances (Taylor, 1
Vinogradov, 1959). A total of sixty–three samples (24 pe
of all samples collected) exceed the threshold level. The cum
tive frequency distribution for cadmium shows the presen
two distinct populations, one normal and the other pos
anomalous. It also shows a positive skew in the direction of
values.

Lead

The geometric mean of lead content of all stream sedi
samples is 7.9 ppm, which is less than the values reporte
Taylor(1964) for crustal abundance (12.5 ppm), or by V
gradov (1959) for its abundance in soil (10.0 ppm). Lead l
seem to be higher in bedrock samples than generally four
crust or soil. The threshold levels of lead in stream sediment
bedrocks are 29.0 ppm and 33.0 ppm Pb, respectively, and

ems to be distributed at random throughout the project area.
sediment sample from the Salinas River near San Ardo con-
ned 102 ppm Pb, and five other stream sediment samples,
stly from Elkhorn Slough drainage, contained anomalous
ounts of lead ranging from 38 to 53 ppm. The cumulative
quency distribution for lead in bedrock samples is primarily
mal, with only one percent of the population being anoma-
s.

Copper and Zinc

he combined total of these elements in the sediments
lyzed was lower than the world-wide average in the crust (Cu
0, Zn 70.0 ppm; Taylor, 1964), or in the soil (Cu 20.0, Zn 50.0
n; Vinogradov, 1959). The King City-San Ardo area shows
h levels of arsenic and cadmium as well as high levels of
per and zinc.

he general levels of copper and zinc in bedrock samples seem
e lower than those in most crustal rocks, but about the same
n soils.

he threshold level for copper is 13.0 ppm in stream sediments
40.0 ppm in bedrocks. For zinc, the threshold level is 74.0
n in stream sediments and 250.0 ppm in bedrocks. Thirty-
ee stream sediment samples contained more copper than the
eshold level; nine samples contained more zinc. The source of
ment for most of these samples was the Middle Miocene
ine Formation.

he cumulative frequency distribution for copper in both
am sediments and bedrocks shows the presence of two popu-
ons, one normal, the other anomalous. The cumulative fre-
ncy distribution for zinc in both stream sediments and
rocks shows lognormal distribution.

Phosphorus

nly the bedrock samples having more than 10 ppm Cd were
yzed for phosphorus. The level of phosphorus seems to be
siderably higher than soil and crustal abundances reported
Taylor (1964) and Vinogradov (1959) respectively. The
shold level is 1.0% P. The cumulative frequency distribution
phosphorus shows the presence of two separate populations;
ercent of the total analyzed samples constitute the anoma-
population.

rom this analytical data, single element distribution maps for
stream sediments and bedrocks were prepared for each
ent (Figures 5 through 17).

CORRELATION

e results of the analyses of the stream sediment and bedrock
ples were processed by means of a stepwise regression com-
r program devised by Health Sciences Computing Facility
C.L.A. Comparisons between concentrations of all elements
d were made in pairs, using regression analysis, in an effort
rn which elements tend to be associated in the materials
d.

tabular summary of the correlation matrices, arranged in
of elements used in the computation, is presented in Tables 3 and 4. Any correlation higher than 0.5000 is higher than 50:50 average; correlation higher than 0.7000 are considered meaningful in the present study. For the stream sediment samples, six pairs of elements (As–Cd, As–Cu, As–Zn, Cd–Cu, Cd–Zn, and Cu–Zn) show significant correlations (Figures 18 through 23): if one element in a pair is high in a sample, the other tends also to be high; however, it is not possible to predict the quantity of the other element by analyzing only one element in each pair.

Table 3. Correlation matrix (stream sediments).

As	*Cd*	*Cu*	*Pb*	*Hg*	*Zn*	
1.000	0.8724	0.7732	0.1859	0.2892	0.7875	As
	1.0000	0.7558	0.0527	0.2414	0.8326	Cd
		1.0000	0.3692	0.4425	0.8816	Cu
			1.0000	0.1994	0.2219	Pb
				1.0000	0.4088	Hg
					1.0000	Zn

Table 4. Correlation matrix (bedrocks).

As	*Cd*	*Cu*	*Pb*	*Hg*	*P*	*Zn*	
1.0000	0.4129	0.4698	0.4502	0.1931	0.3224	0.5278	As
	1.0000	0.7548	0.2699	0.2532	0.9492	0.9123	Cd
		1.0000	0.3189	0.1615	0.8409	0.9020	Cu
			1.0000	0.1059	0.2199	0.3803	Pb
				1.0000	0.3710	0.2060	Hg
					1.0000	0.9478	P
						1.000	Zn

An attempt was made to correlate the analytical results of stream sediment chemistry with the geology of the area to determine which bedrock units were parents of the anomalously high values of each tested element. This correlation of stream sediment chemistry with the geology of the area was inferential at best, because some of the samples had accumulated from a number of possible parent rocks, and at that stage no analyses had been made to determine which bedrock formations have concentrations of one or more of the elements tested. A transparent copy of the stream sediment sample locations map was positioned over the geological map of Monterey County (Hart, 1966), and the possible sources of each sediment then were determined in terms of geological formations exposed in the drainage basins. Wherever there was doubt, the two most likely sources were considered. The stream sediment samples collected from the Salinas and Carmel Rivers and from the Arroyo Seco were not used in this correlation, because they were transported from long distances and represent a heterogeneous mixture of sediments received from many geological formations. The scope of this first stage of the project did not include the testing of individual geological units.

Table 5 lists the range and average amounts of the six elements in stream sediment samples derived from the various geological formations in the project area.

Among the bedrock samples, six pairs of elements (Cd–Cu, Cd–P, Cd–Zn, Cu–Zn, P–Cu, and P–Zn) show significant associations (Figure 24 through 29). Samples belonging to phosphatic beds appeared to have high-cadmium contents. In fact, almost all phosphatic rocks in the area have high cadmium contents except eleven samples which have high cadmium but low phosphorus. Four samples have free-sulfur encrustations that probably resulted from sublimation of sulfide solutions. All

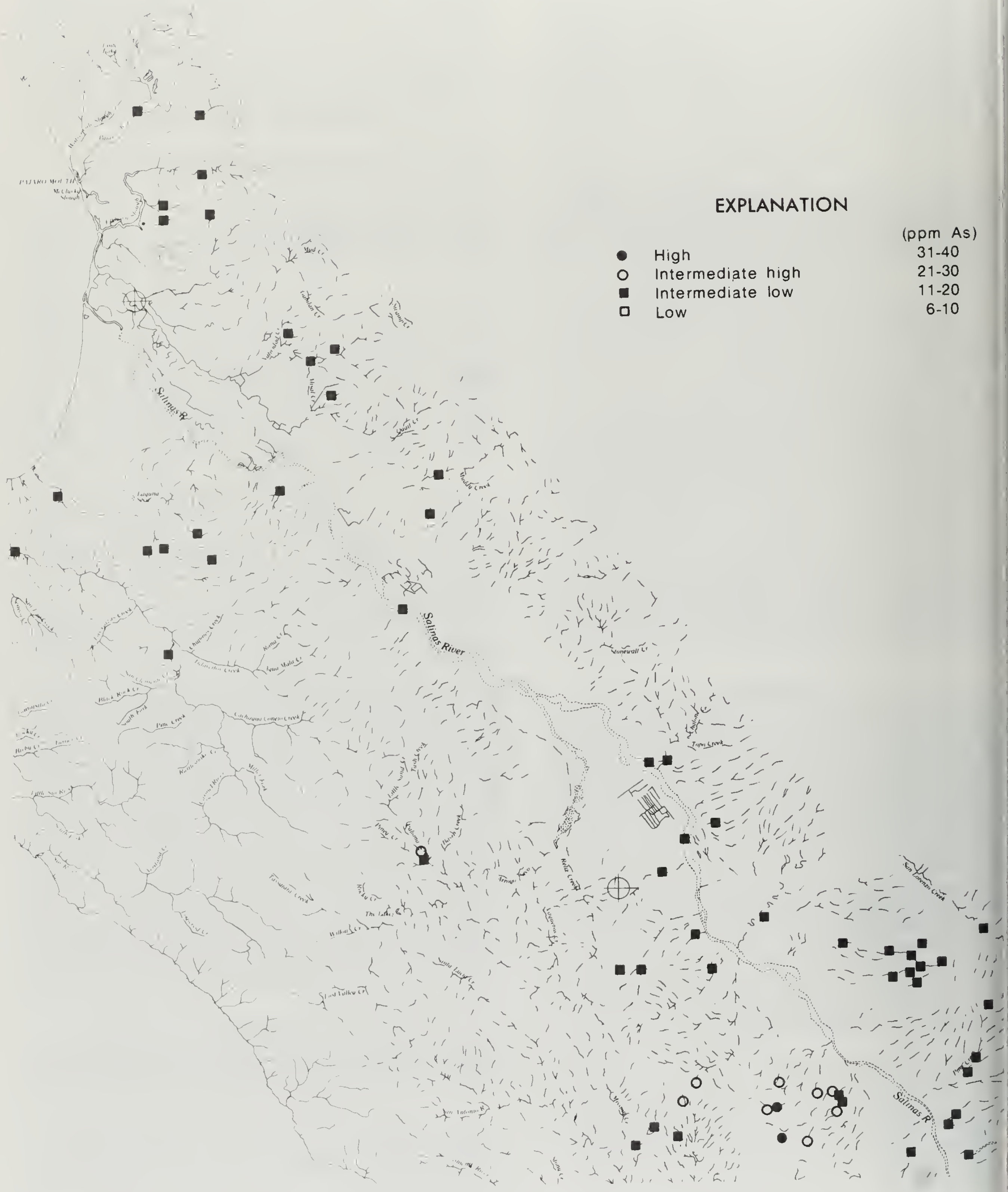
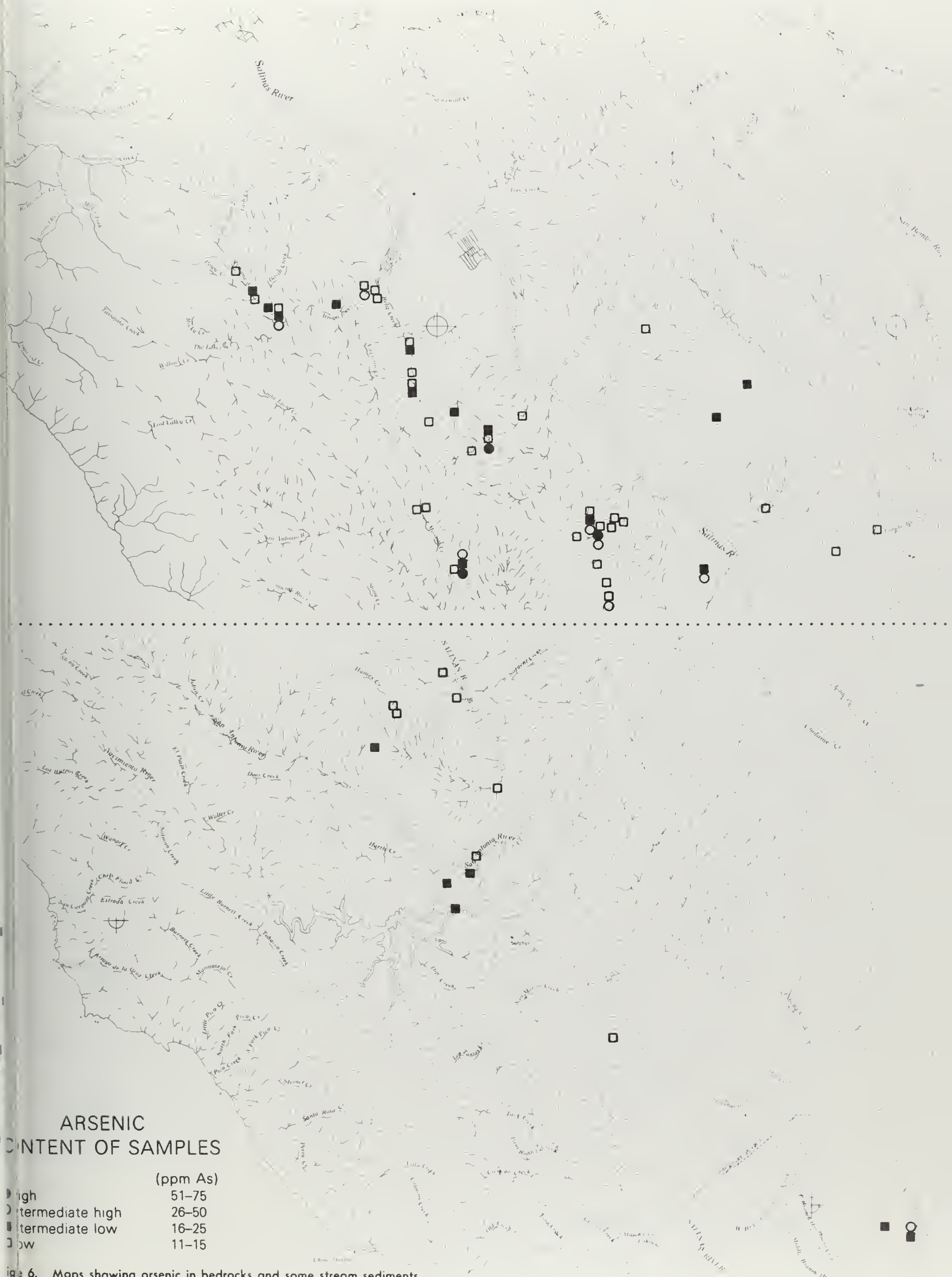


Figure 5. Map showing arsenic in stream sediments.



ARSENIC
ONTENT OF SAMPLES

	(ppm As)
igh	51–75
termediate high	26–50
termediate low	16–25
ow	11–15

ig. 6. Maps showing arsenic in bedrocks and some stream sediments.

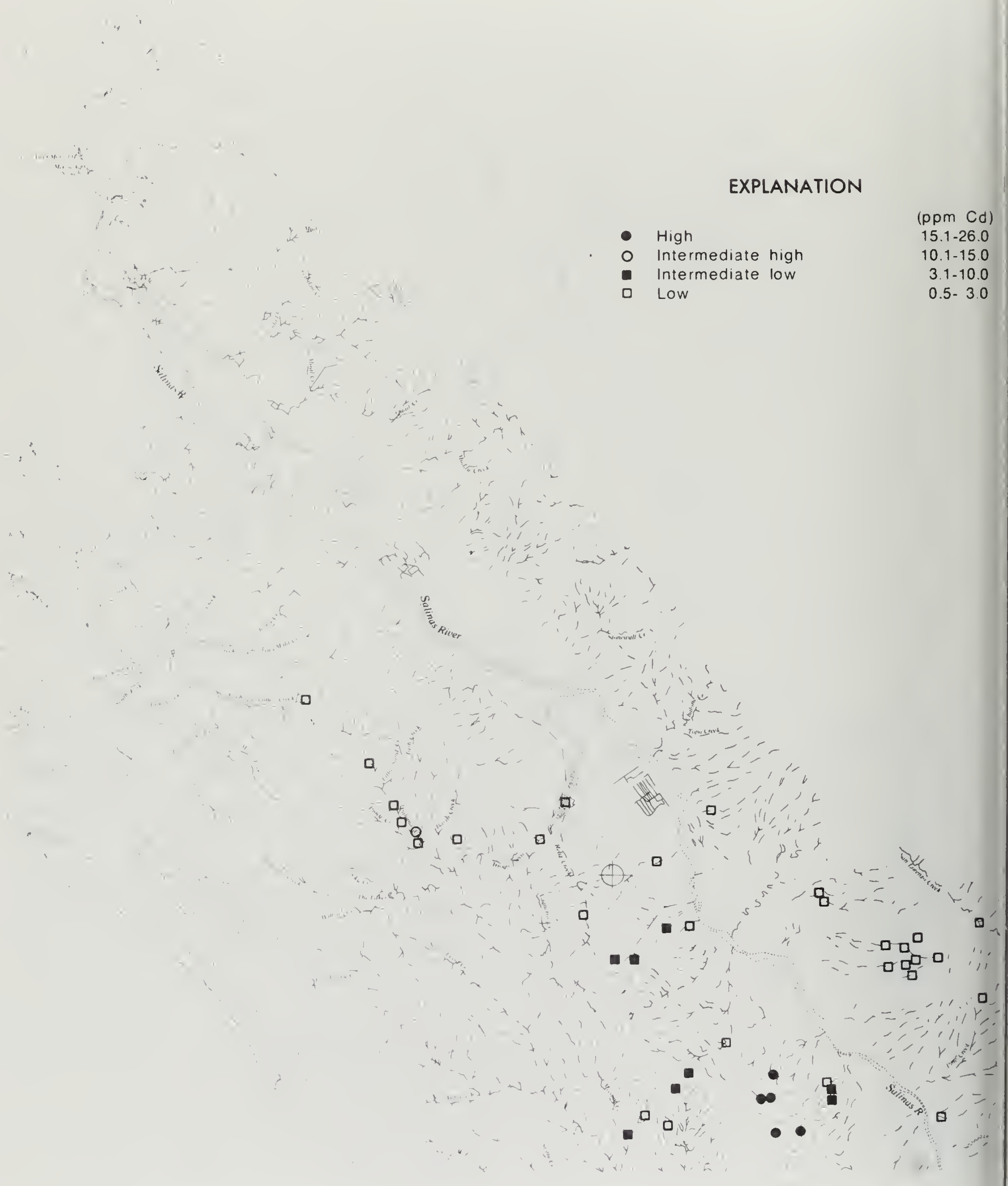
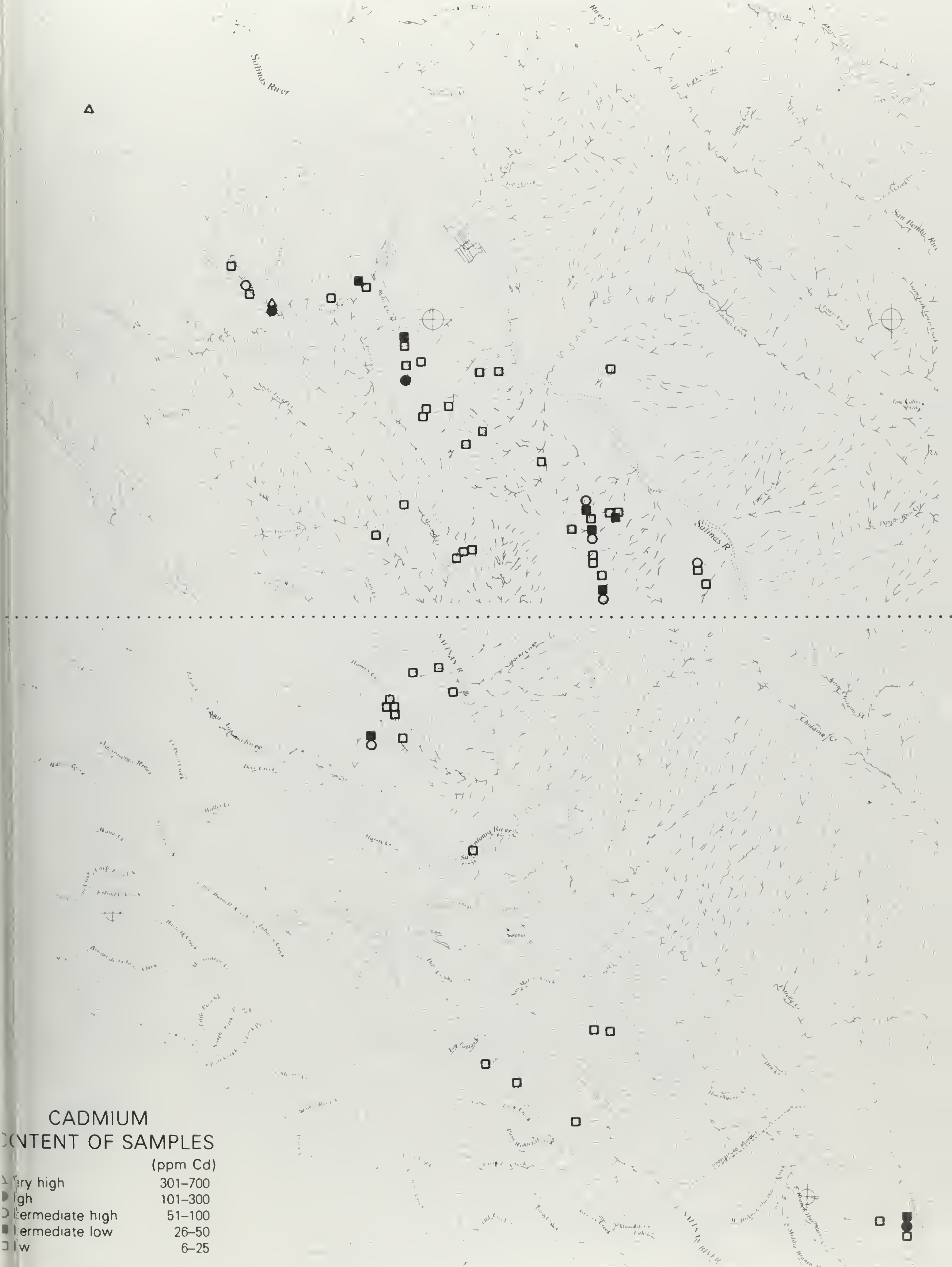


Figure 7. Map showing cadmium in stream sediments.



igu 8. Maps showing cadmium in bedrocks and some stream sediments.

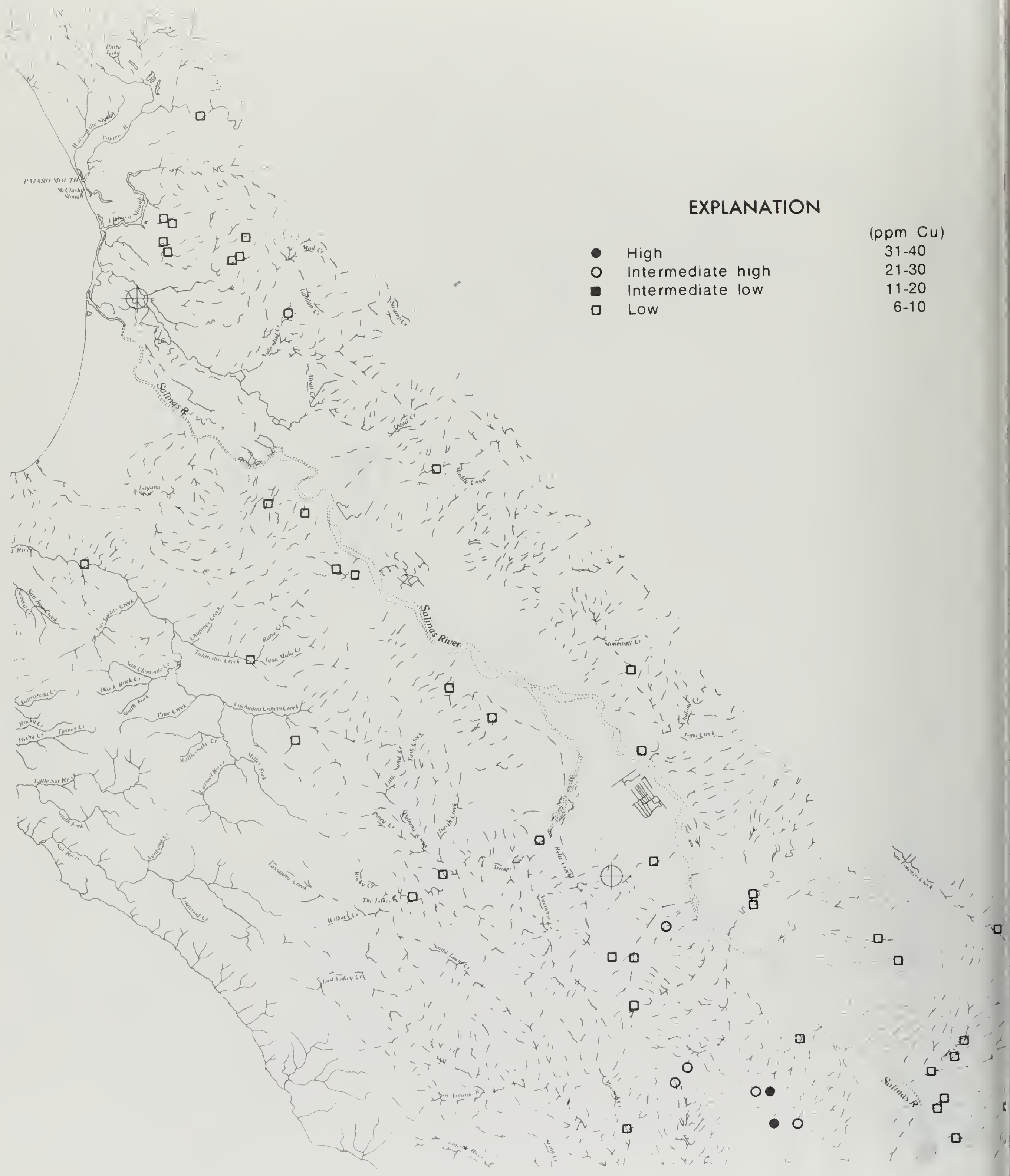
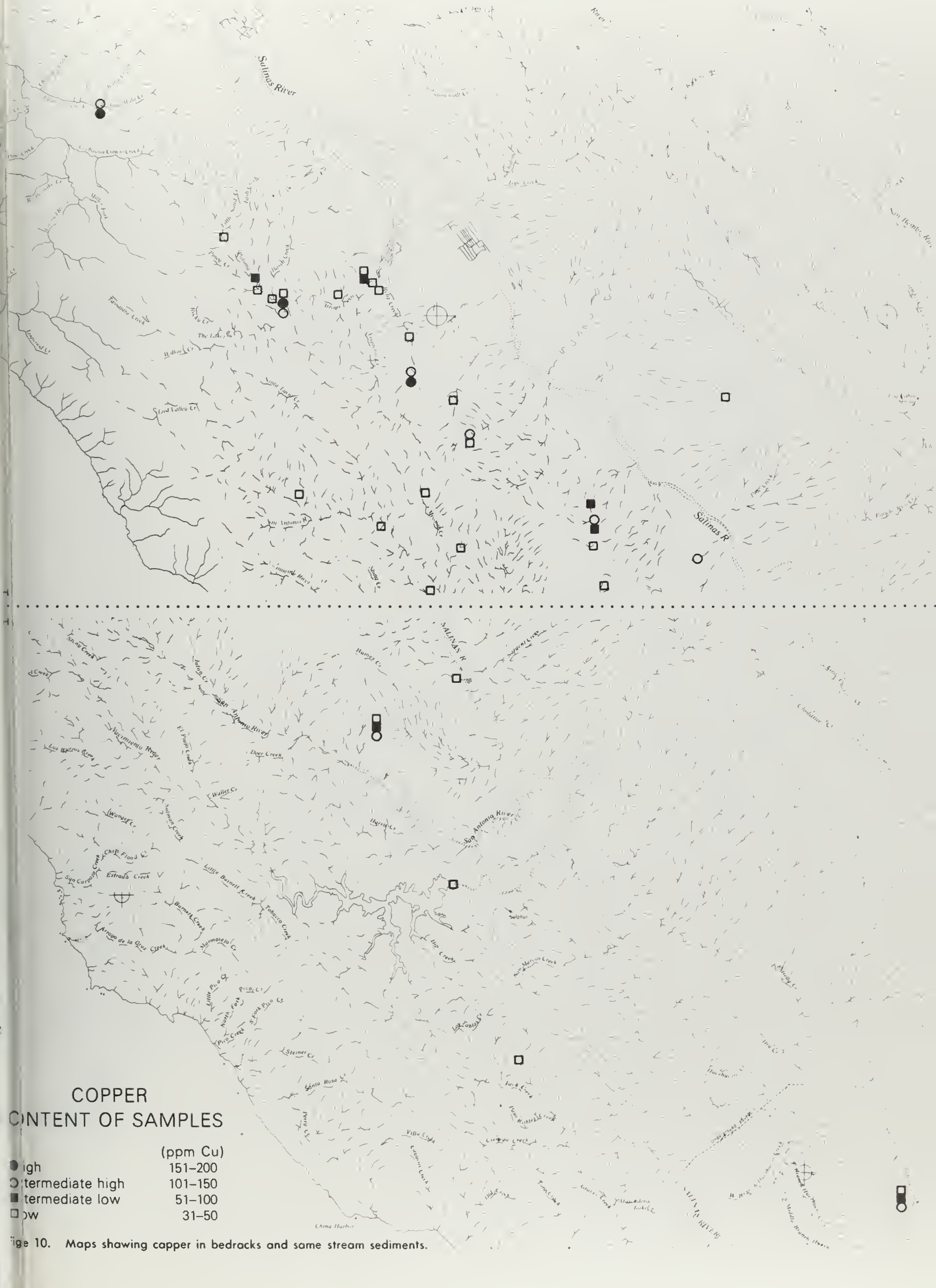


Figure 9. Map showing copper in stream sediments.



ige 10. Maps showing copper in bedrocks and some stream sediments.

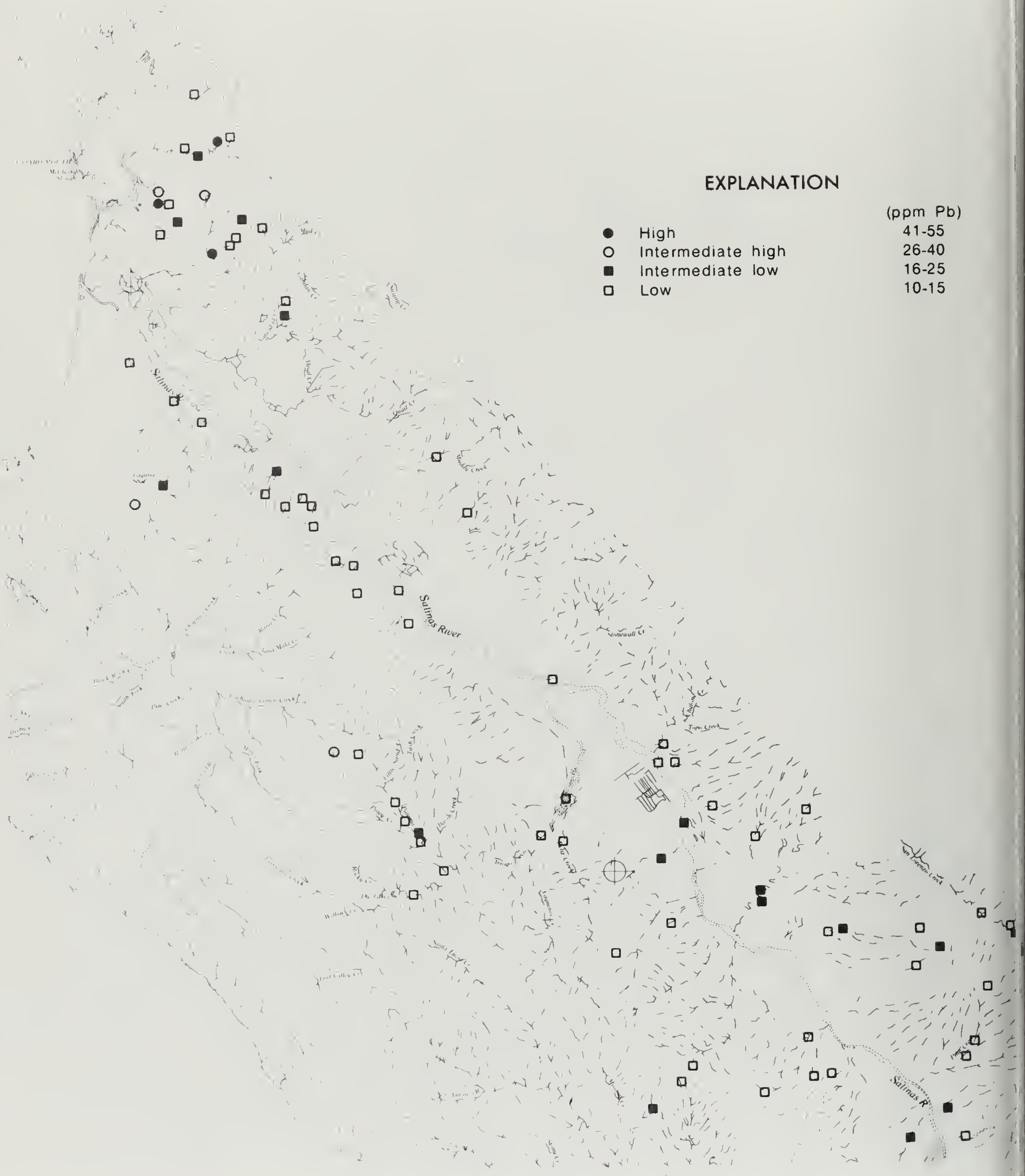


Figure 11. Map showing lead in stream sediments.

gu 12. Maps showing lead in bedrocks and some stream sediments.

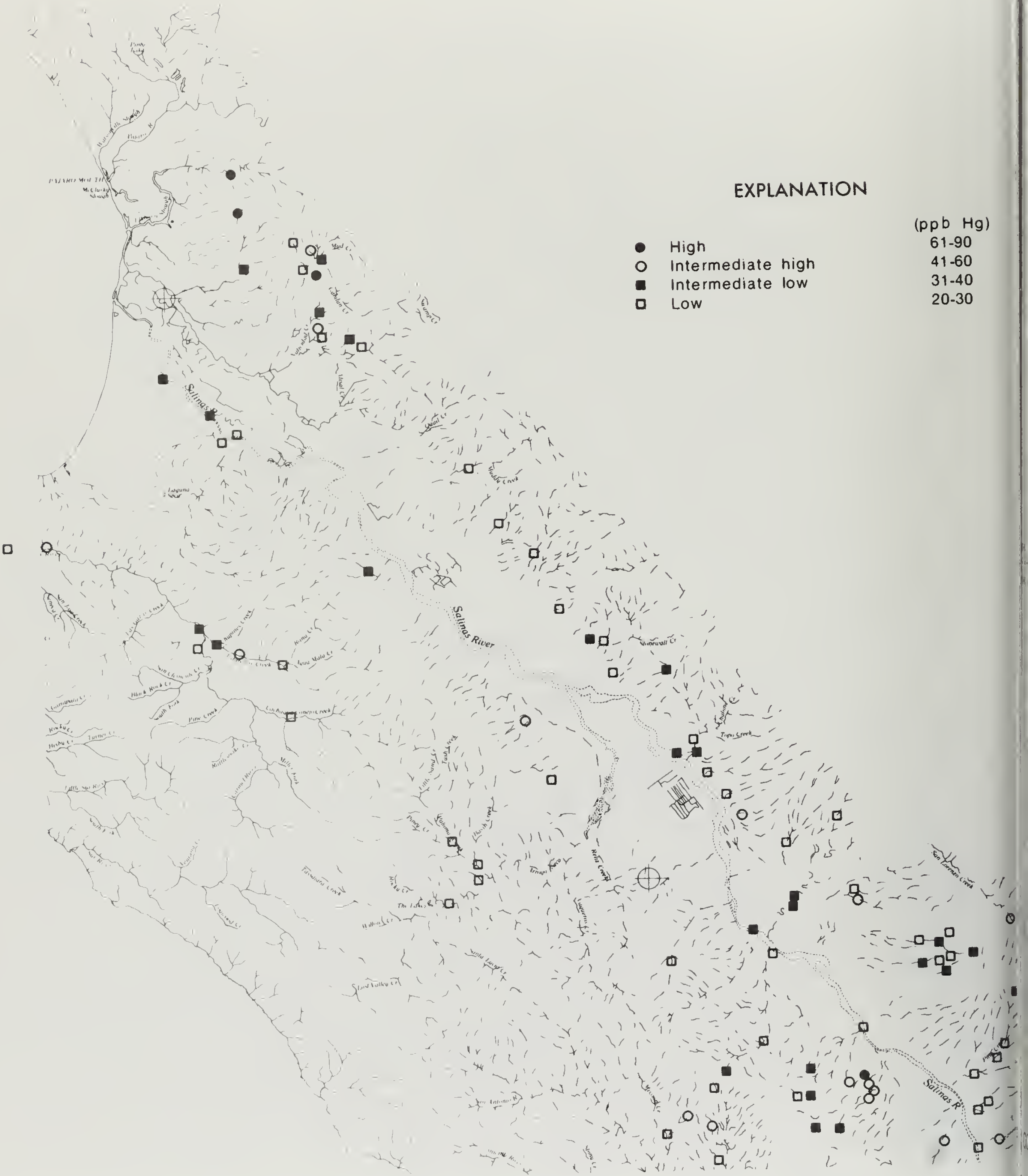


Figure 13. Map showing mercury in steam sediments.

MERCURY
C NTENT OF SAMPLES

	(ppb Hg)
● gh	251–560
○ termediate high	101–250
■ termediate low	51–100
□ w	25–50

gu 14. Maps showing mercury in bedrocks and some stream sediments.

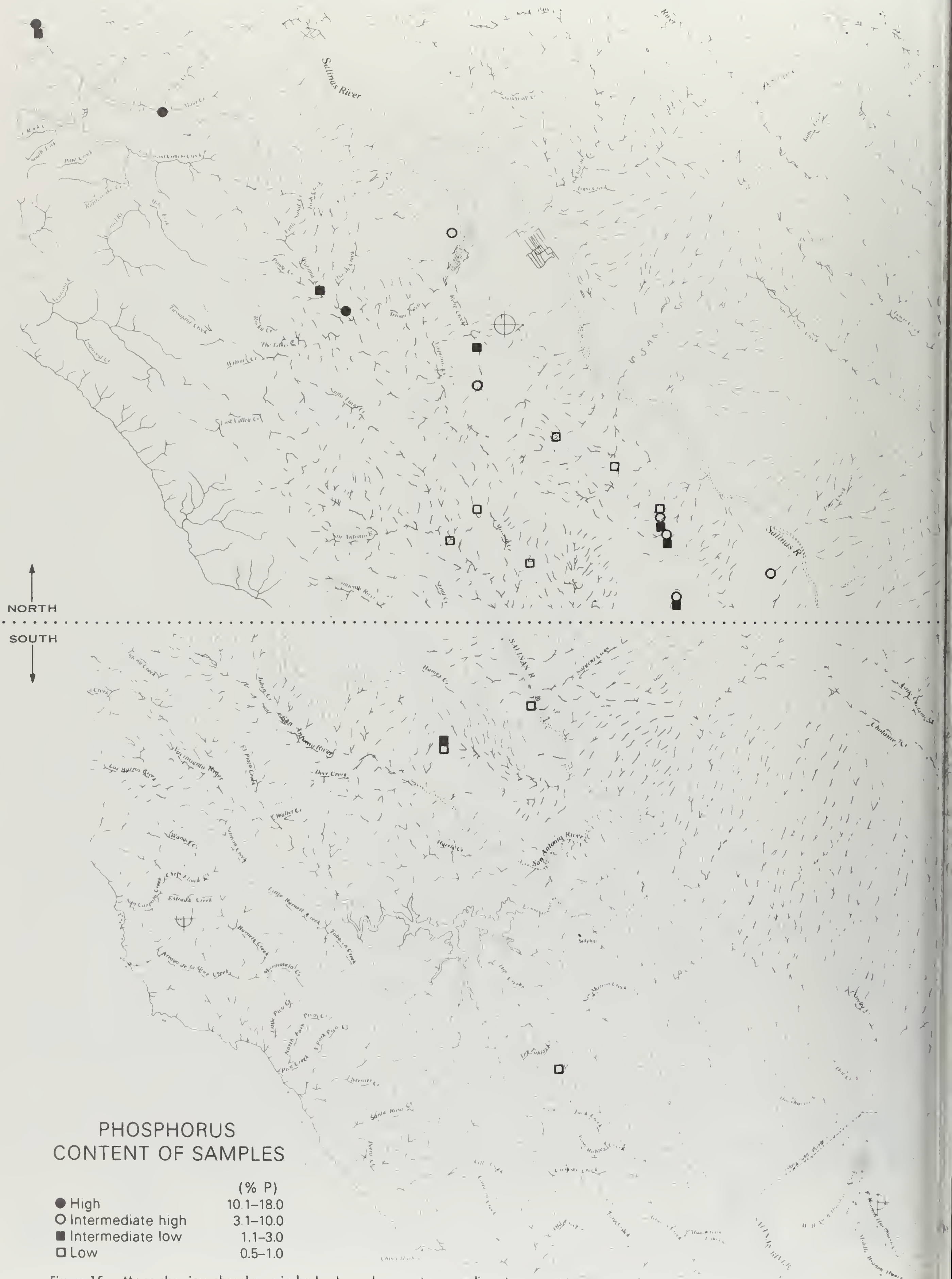
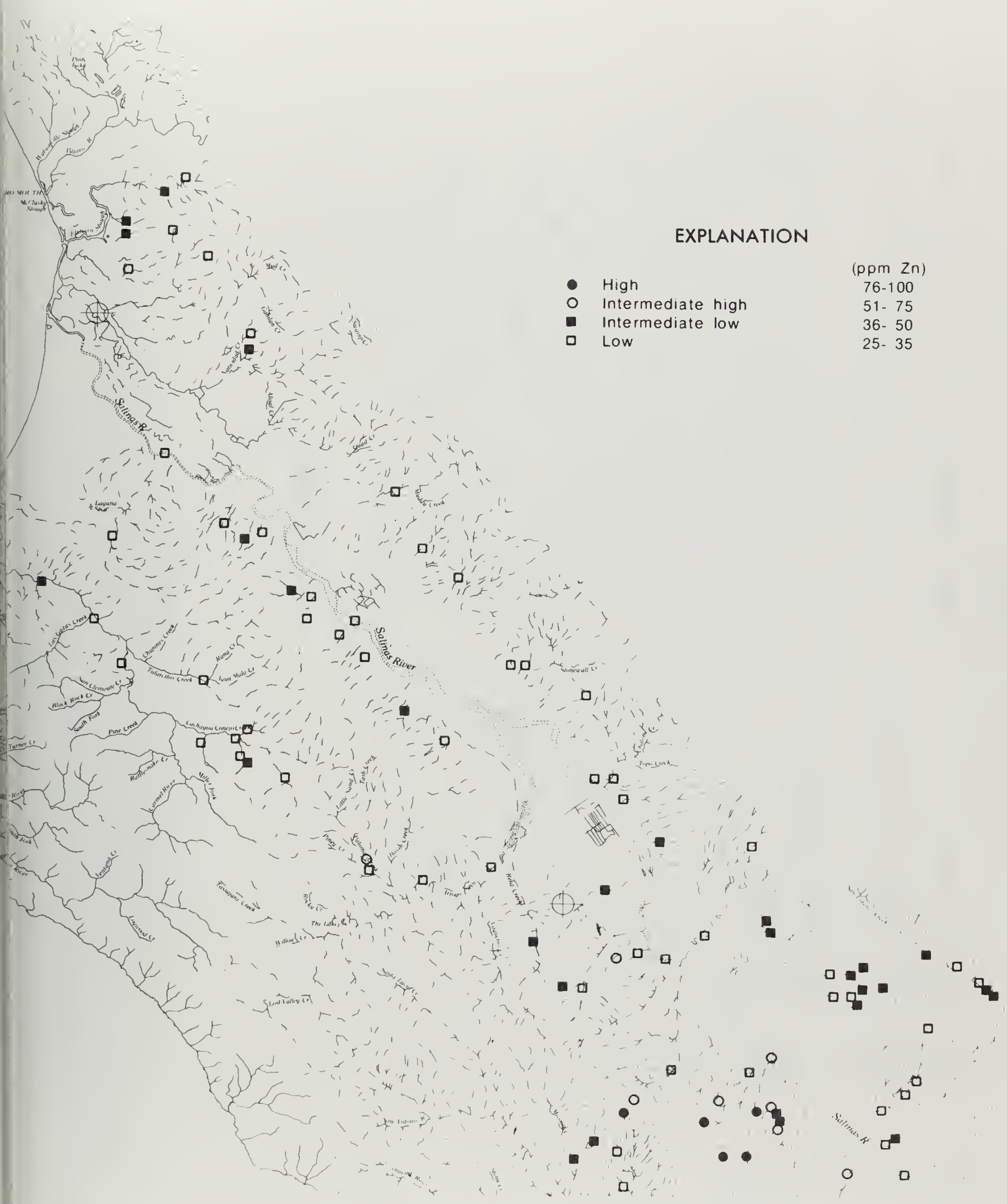


Figure 15. Maps showing phosphorus in bedrocks and some stream sediments.



ig 16. Map showing zinc in stream sediments.

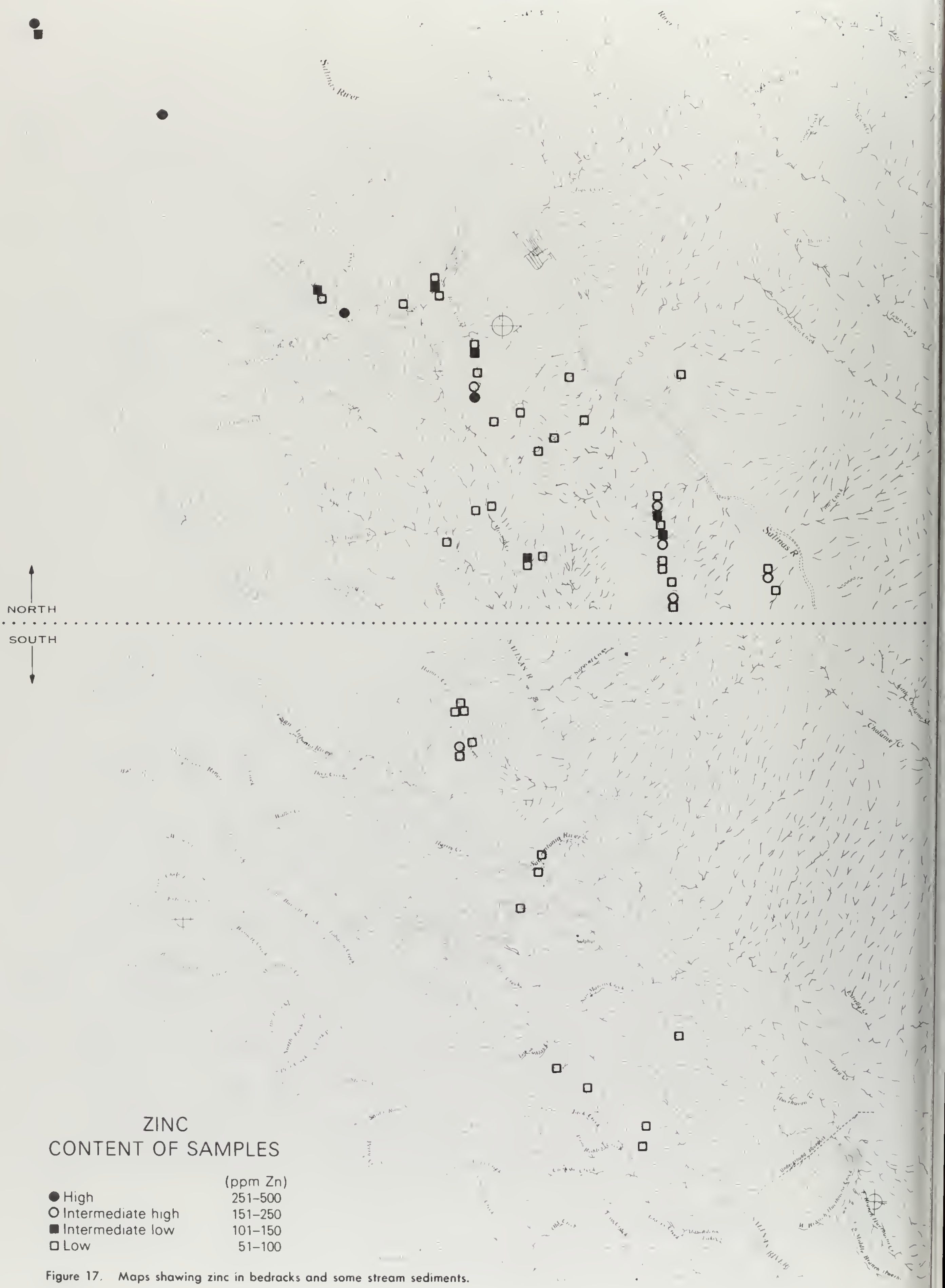


Figure 17. Maps shawing zinc in bedracks and some stream sediments.

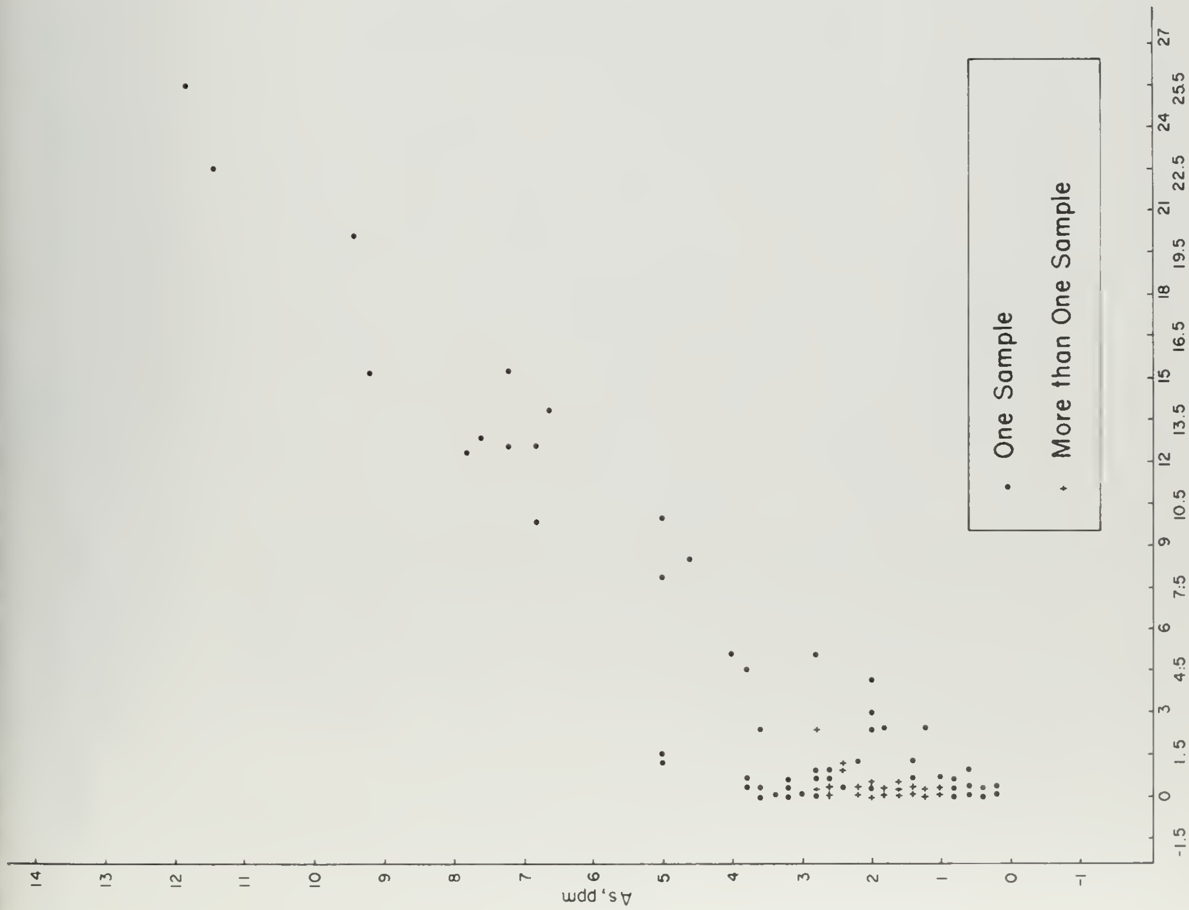


Figure 18. Correlation between arsenic and cadmium in stream sediments.

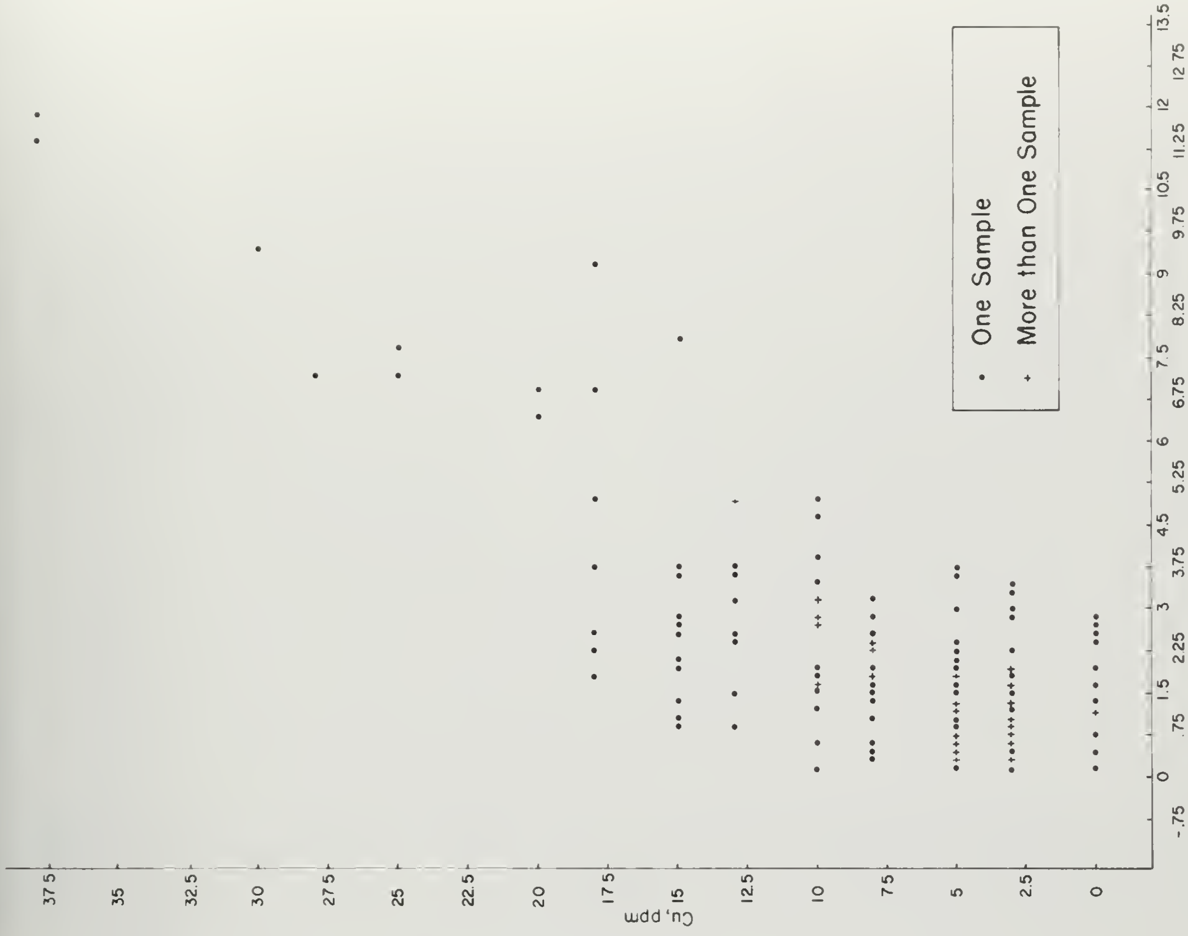


Figure 19. Correlation between arsenic and copper in stream sediments.

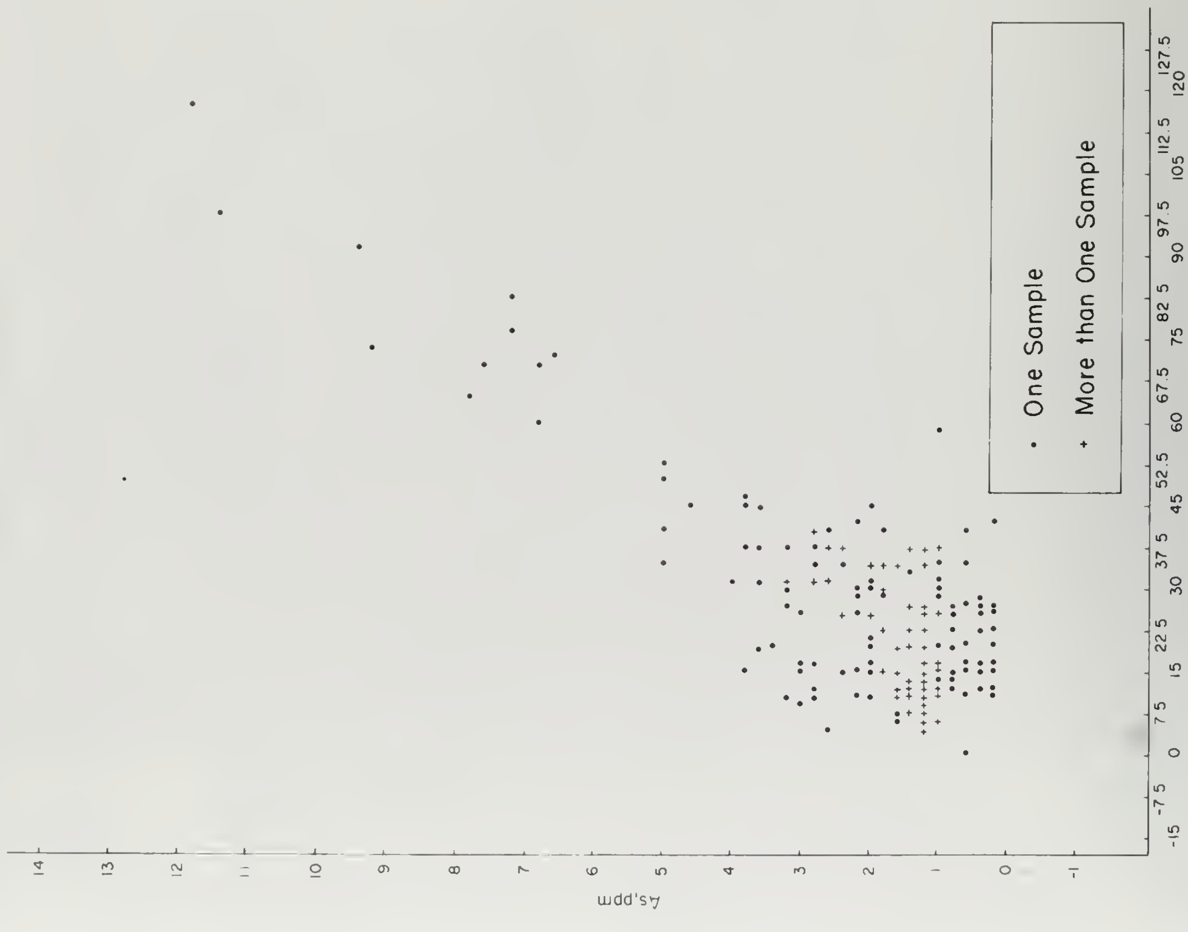


Figure 20. Correlation between arsenic and zinc in stream sediments.

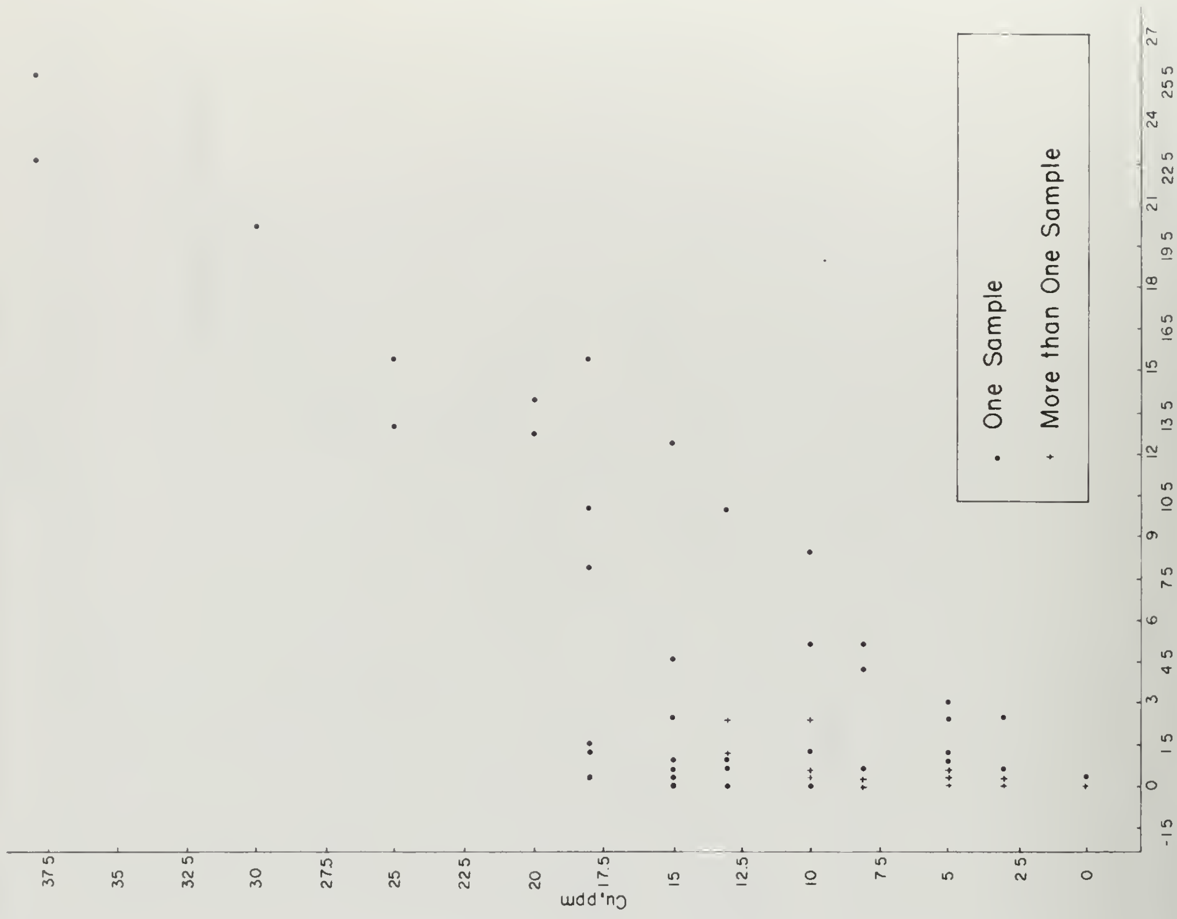


Figure 21. Correlation between cadmium and copper in stream sediments.

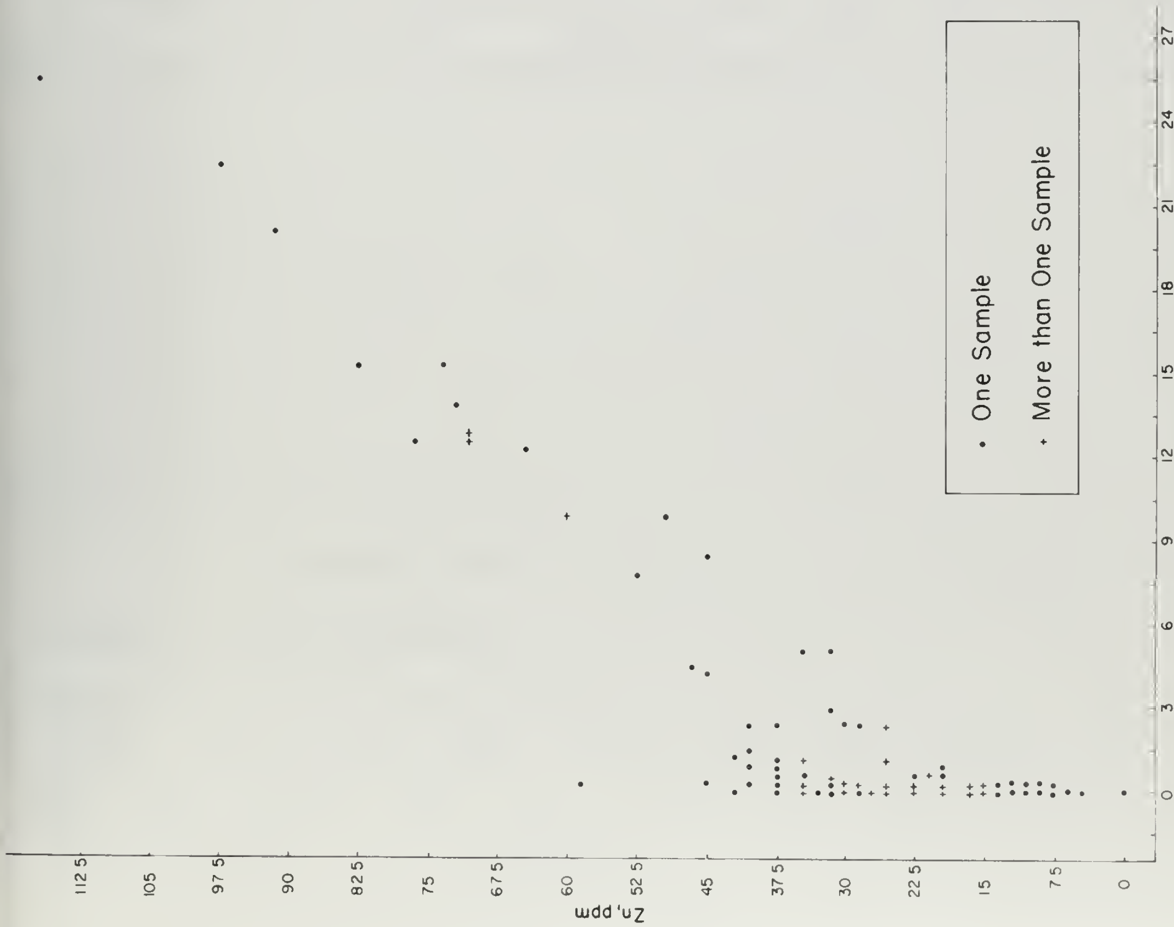


Figure 22. Correlation between cadmium and zinc in stream sediments.

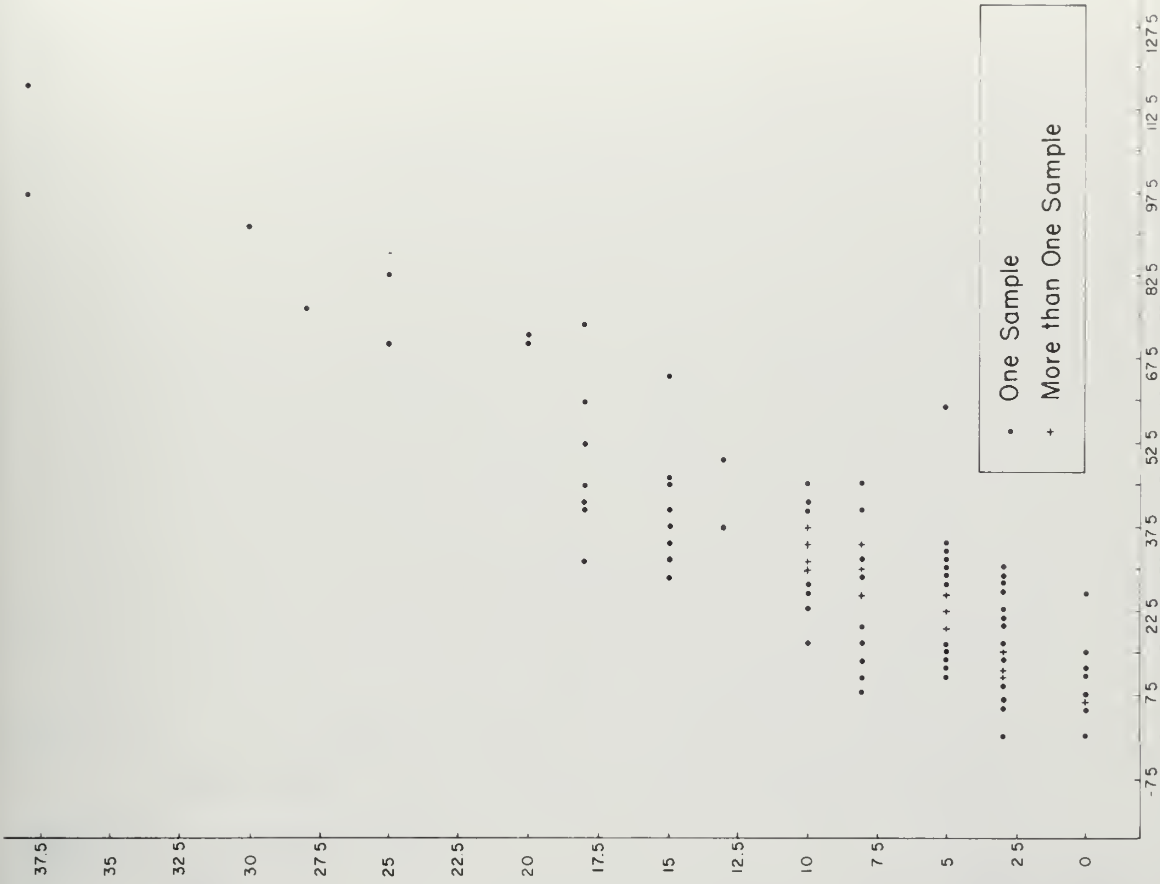


Figure 23. Correlation between copper and zinc in stream sediments.

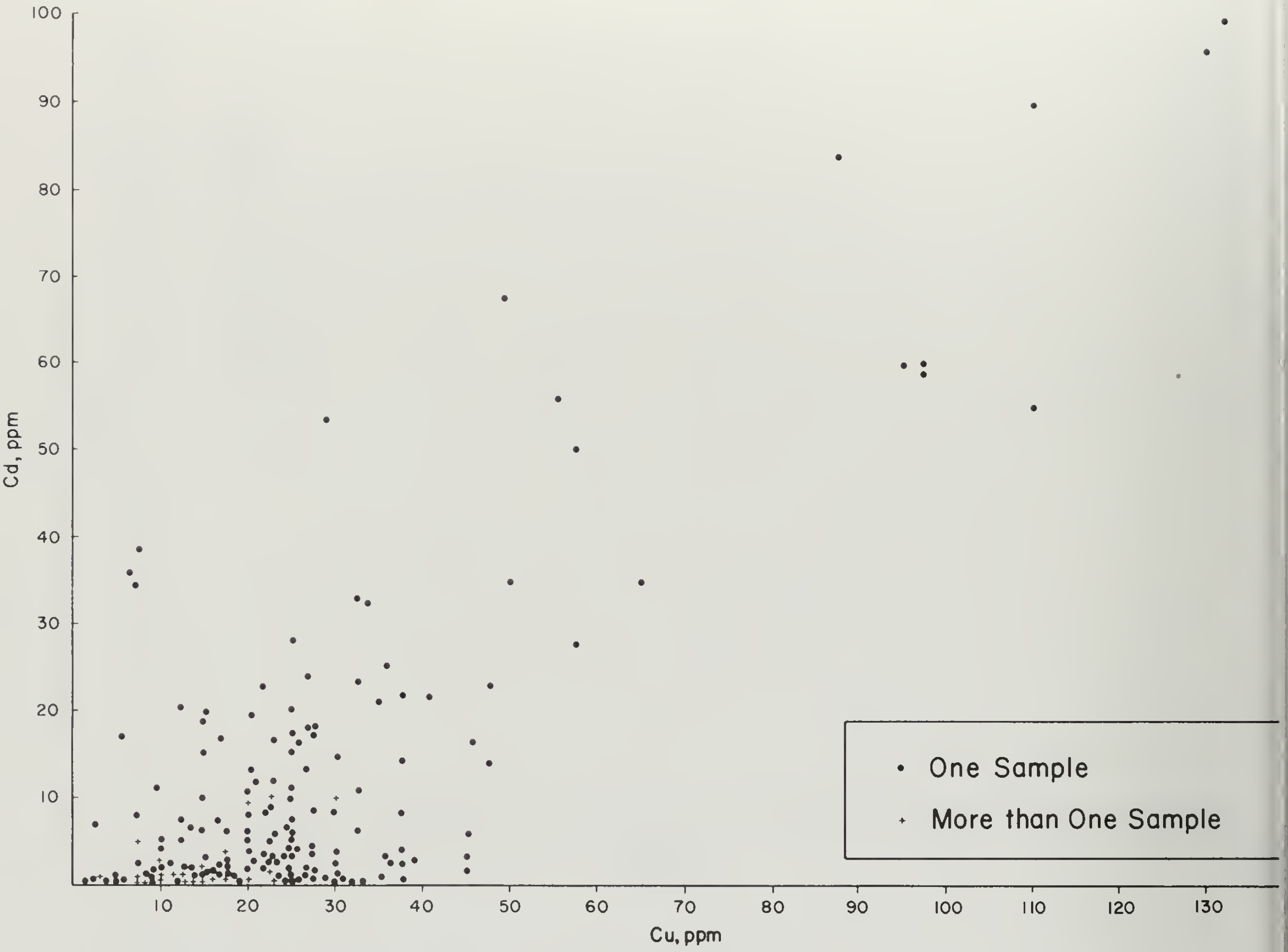


Figure 24. Correlation between cadmium and copper in bedrocks and some stream sediments.

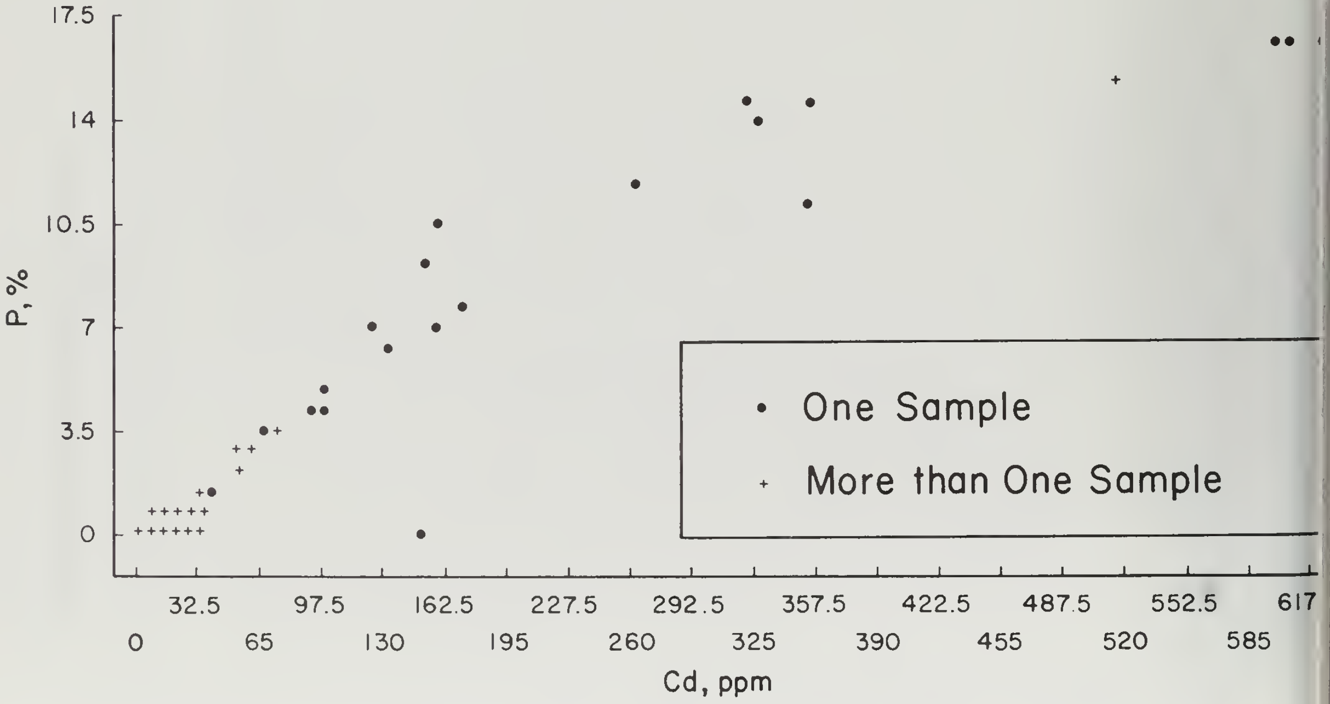


Figure 25. Correlation between cadmium and phosphorus in bedrocks and some stream sediments.

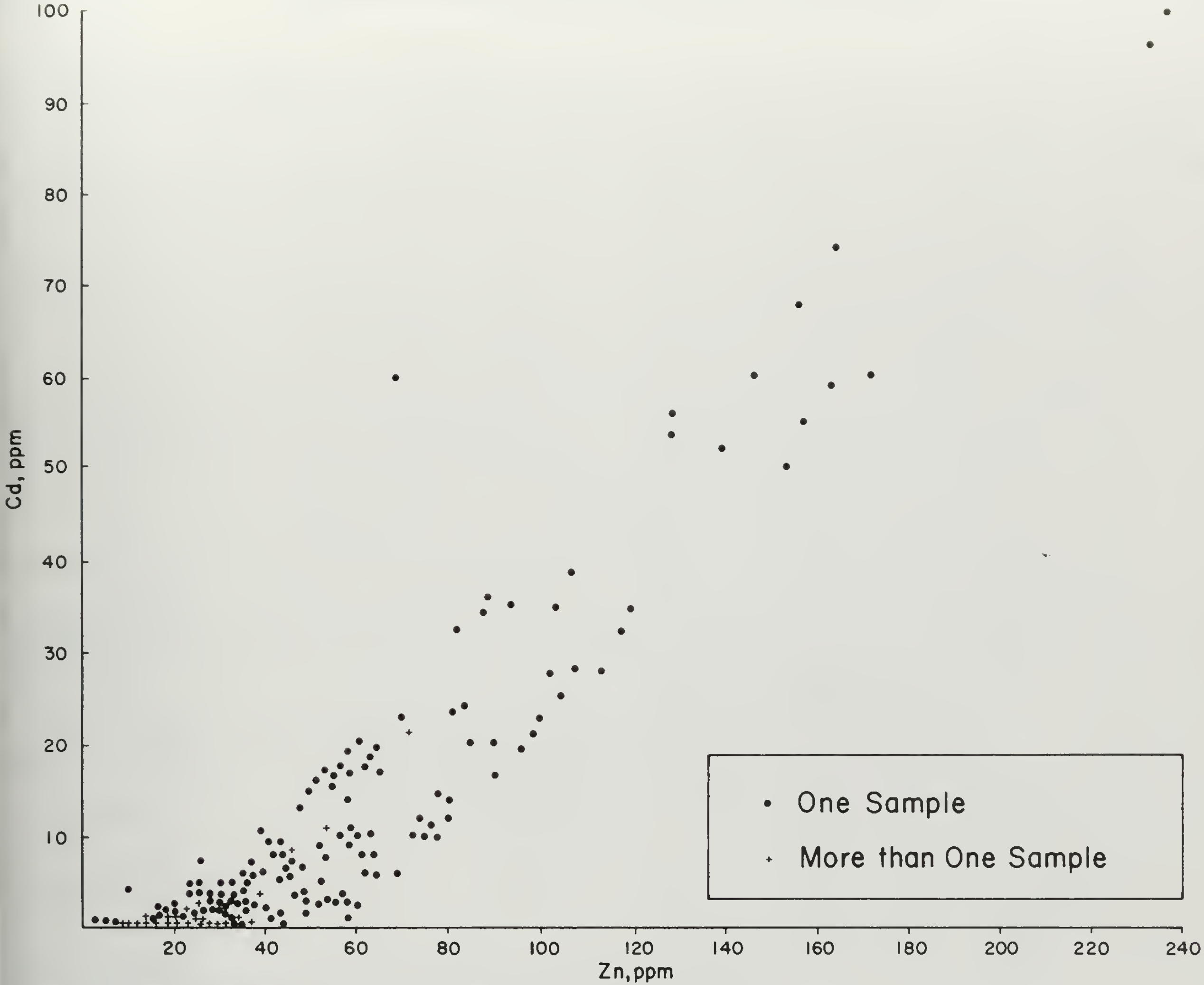


Figure 26. Correlation between cadmium and zinc in bedrocks and some stream sediments.

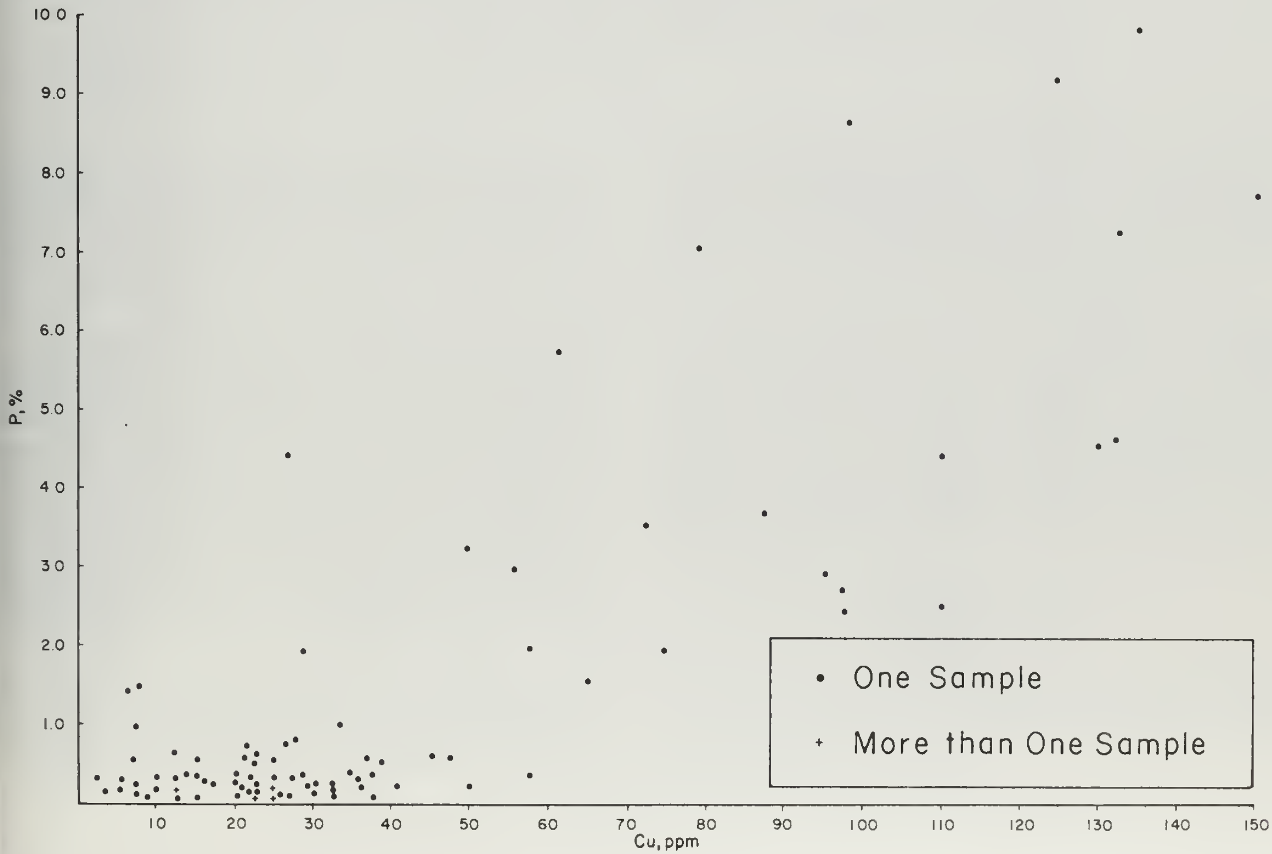


Figure 27. Correlation between phospharus and copper in bedrocks and stream sediments.

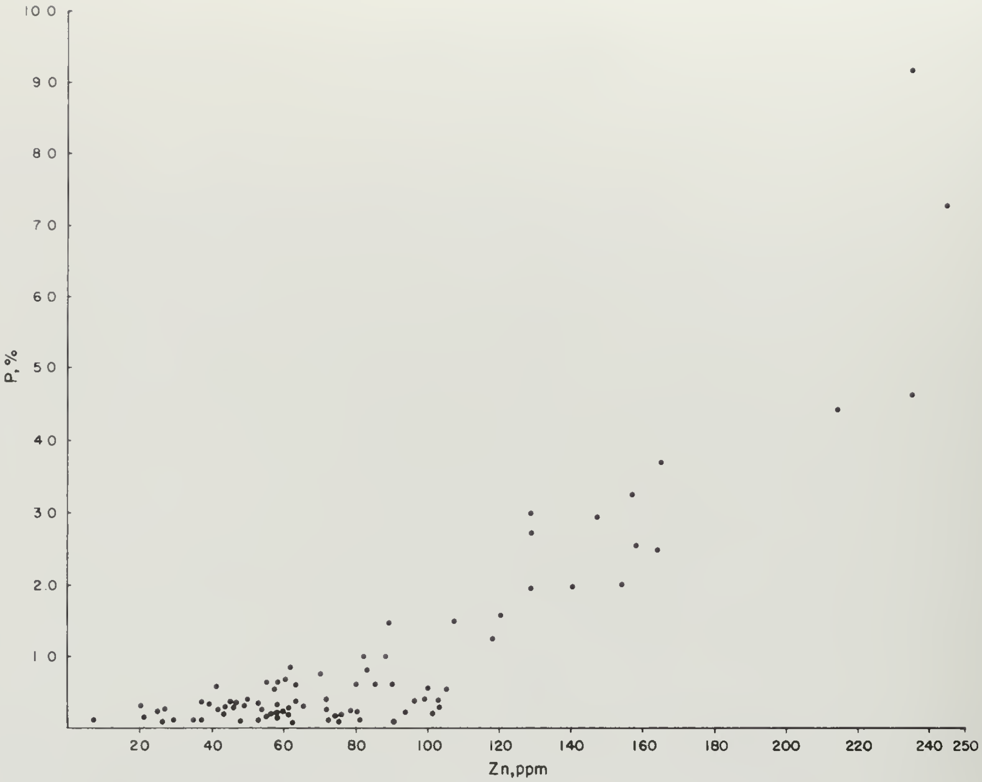


Figure 28. Correlotion between copper ond zinc in bedrocks ond some streom sediments.

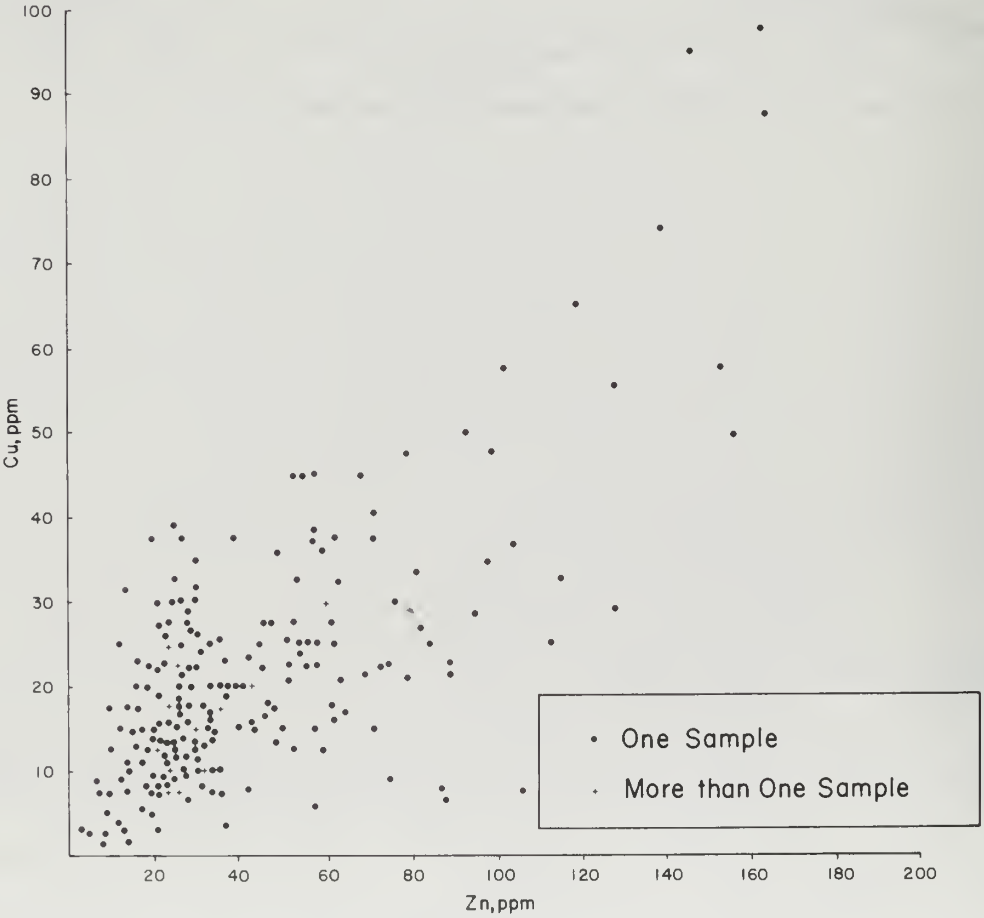


Figure 29. Correlotion between phosphorus ond zinc in bedrocks ond some streom sediments.

ble 5. Correlation of geology[1] and stream sediment chemistry.

Geological Formations	As(ppm)		Cd(ppm)		Cu(ppm)		Pb(ppm)		Hg(ppb)		Zn(ppm)	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Qal lluvium (8)[2]	0.57-2.86	1.7	0-0.42	0.2	3-8	5	0-20	8	0-40	17	10-35	22
Qal/Pml lluvium/Middle or Lower Pliocene arine (10)	1.80-4.76	3.4	0.1-0.64	0.4	8-28	14	10-23	16	21-88	44	30-700*	43
Qt iver Terrace & Fan Deposits (27)	0.10-6.83	1.8	0-13.2	1.6	0-20	7	0-25	10	0-61	24	5-82	26
Qt/Gr iver Terrace & Fan Deposits/ esozoic Granitic Rocks (9)	0.12-1.80	1.0	0-0.6	0	0-10	4	0-13	6	0-46	20	6-34	18
Qc leistocene Nonmarine (19)	0.70-7.55	2.3	0-0.46	0.1	3-28	10	8-53	18	0-88	16	6-180*	25
Qp lio-Pleistocene Nonmarine (8)	0.65-5.95	2.3	0.04-2.13	0.5	0-5	3	0-28	8	0-53	13	7-25	18
Qp/Pml lio-Pleistocene Nonmarine/Middle lower Pliocene Marine (10)	1.30-6.13	3.2	0.1-1.2	0.8	5-15	11	5-20	9	13-48	30	10-67	35
Mu pper Miocene Marine (7)	0.50-2.85	1.9	0.14-4.23	1.0	0-15	4	0-25	6	0-48	10	7-50	22
Mm iddle Miocene Marine (24)	0.18-11.40	4.0	0.18-24	7.5	3-23	12	0-20	10	0-512*	25	14-100*	50
Gr sozoic Granitic Rocks (21)	0.30-4.25	1.3	0-0.4	0.1	3-13	5	0-15	7	0-41	23	11-57	24
m-Ls e-Cretaceous Metamorphic cks (11)	0.10-1.93	0.8	0-0.1	0	3-15	6	0-15	5	0-75	24	10-55	27

NOTES:

[1] Refer to Hart, E.W., 1966 for detailed geology of the project area.

[2] The number in brackets for each geological formation denotes the number of samples taken into consideration for calculating the average values. Also, only units represented by 8 or more samples, were considered in the geology-chemistry correlation.

* Anomalously higher values not considered for average.

e high cadmium contents. High cadmium contents also were ond in three samples collected from the crushed rocks in the conada fault zone and in four stream sediment samples from h Hames Valley. According to Burau (Richard G. Burau, versity of California at Davis, personal communication, 4), the soils in Hames Valley also are high in cadmium.

view of the demonstrated relationships between phosphou and cadmium, a decision was made to analyse phosphatic amples available from areas outside the study area. In general, sphatic rocks from other parts of the United States do not essarily have high cadmium contents (Table 6). Some saml, however, had enough cadmium, (i.e., 110 ppm Cd in phoste from Idaho) to warrant concern about the possibility of l pockets of contaminated phosphatic rocks in other United tes or world localities. It is therefore recommended, that the U. Geological Survey or a similar institution undertake an nvestigation of cadmium contamination in phosphatic rocks in aous locations.

erard Bond (personal commmunication, 1974) of the Uniersity of California at Davis has found that samples of phoshic rock which is exported from Vernal, Utah, to Canada for as a rock phosphate fertilizer, have a Cd content of 10 ppm. Some phosphatic rock quarries in Wyoming have 30 to 150 ppm Cd, depending on sample location. Rock from these quarries is used as a rock phosphate fertilizer in the United States and is definitely contaminating agricultural soil and, in turn, the crops which grow on them. These observations support the necessity for further studies of cadmium in phosphatic rocks.

The geology of the study area was correlated with the chemistry of the area (Table 7). Unusually high amounts of cadmium occur in the phosphatic beds of the Monterey and Pancho Rico Formations, in stream sediments of Hames Valley, and in samples from the Rinconada fault zone. These samples are also high in arsenic, copper, lead, and zinc. Perhaps cadmium contamination in the phosphatic rocks is the result of Miocene volcanic activities.

CONCLUSIONS

- Six pairs of elements (As–Cd, As–Cu, As–Zn, Cd–Cu, Cd–Zn, Cu–Zn) in the stream sediments and six pairs of elements (Cd–Cu, Cd–P, Cd–Zn, Cu–Zn, P–Cu, P–Zn) in the bedrock show significant associations.

Table 6. Phosphorus and cadmium determination in samples from other parts of the United States.

Lab. Numbers	*P (%)*	*Cd ppm*	*Locations*	*Source*
365/73	16.42	11.8	National Bureau of Standard 120a, Florida	National Bureau of Standards, Washington, D.C.
366/73	9.84	30	Pamlico River, North Carolina	Fred Kelley, Cal. Div. Mines & Geol., S.F., CA.
367/73	2.53	1.6	Magadalena Bay, Baja California	Fred Kelley, Cal. Div. Mines & Geol., S.F., CA.
372/73	12.81	11.2	Clay Canyon, Utah	J.H. Madsen, Jr., University of Utah, Salt Lake City,
373/73	14.21	110	Idaho	L.S. Praler, Bureau of Mines & Geology, Moscow, Ida
377/73	11.96	60	Pine Mountain, CA	Fred Kelley, Cal. Div. Mines & Geol., S.F., CA.
378/73	8.51	30	Pine Mountain, CA	Fred Kelley, Cal. Div. Mines & Geol., S.F., CA.
379/73	13.35	11.3	San Juan Capistrano, CA	Edmund Kiessling, Cal. Div. Mines & Geol., L.A., CA
380/73	7.94	2.2	Dredge Sample, off so. CA Coast	Jack Veder, U.S.G.S., Menlo Park, CA.
381/73	3.45	13.6	Dos Pueblos Creek, Naples Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
382/73	2.77	21	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
383/73	5.13	50	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
384/73	4.43	31	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
385/73	0.61	4.4	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
386/73	0.20	3.4	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
387/73	0.50	1.6	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
388/73	0.52	3	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
389/73	1.28	2.2	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
390/73	0.21	2	Trench, Chico Martinez Section, CA.	H. Gower, U.S.G.S., Menlo Park, CA.
391/73	15.32	1.6	Florida	D.A. Graetz, University of Florida, Gainsville, Florida
392/73	2.40	3.8	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
393/73	2.80	5	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
394/73	2.90	5	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
395/73	11.50	2	Santa Margarita, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
396/73	4.90	89	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
460/73	1.5	7.5	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
461/73	29.0	22.5	Wheeler Springs, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
462/73	0.11	2.0	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
463/73	3.08	171.5	Santa Margarita, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
464/73	1.46	7.2	Lopez Mountain, CA	Earl Hart, Cal. Div. Mines & Geology, S.F., CA.
466/73	14.05	2.6	Dredge Sample, off So. CA Coast	Jack Veder, U.S.G.S., Menlo Park, CA.
467/73	9.25	1.9	Dredge Sample, off So. CA Coast	Jack Veder, U.S.G.S., Menlo Park, CA.
468/73	9.82	0	Dredge Sample, off So. CA Coast	Jack Veder, U.S.G.S., Menlo Park, CA.
469/73	9.03	1.2	Dredge Sample, off So. CA Coast	Jack Veder, U.S.G.S., Menlo Park, CA.

Table 7. Correlation of geology[1] and bedrock chemistry.

STRATIGRAPHIC CLASSIFICATION OF SAMPLES	MAP SYMBOL	NO. OF SAMPLES	ARSENIC (ppm)		CAOMIUM (ppm)		COPPER (ppm)		LEAO (ppm)		MERCURY (ppb)		PHOSPHORUS (%)		ZINC (ppm	
			Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Aver
Stream sediments	---	8	4-13	9	3-28	11	10-25	20	10-30	20	0-40	17	0.06-0.16	0.09(4)[2]	28-114	6
Rinconada fault zone	---	3	10-14	12	17-22	19	25-38	30	18-27	22	0-43	19	0.17-0.36	0.28	53-72	6
PALEOZOIC																
Metasedimentary rocks.	mSc[4]/	2		1		0	19-24	21	12-19	16		0		n.d.	26-31	2
MESOZOIC																
Granitic rocks	gr,grd, gqd,gb	5	0-2	1		0	12-33	19	15-21	18	0-11	5		n.d.	15-34	2
UPPER CRETACEOUS AND PALEOCENE																
Unnamed units (marine)	KTg	3	1-3	2		0	9-13	12	16-20	18		0		n.d.	20-25	2
EOCENE																
The Rocks Sandstone.	Tr	1		3		0		8		17		15		n.d.		
OLIOGENE																
Berry Formation.	Tbe	2	0-4	2		0	8-30	19	18-19	19	0-5	3		n.d.	10-26	1
Church Creek Formation	Tce	2		2		0	8-15	12	19-23	21	435-560	498		n.d.	23-33	2
OLIGOCENE-MIOCENE																
Vaqueros Sandstone (marine). .	Tvq	3	1-3	2		0	2.5-12.5	6.0	15-20	17	0-5	4		n.d.	9-21	1
	Tvt	1		0.5		0		13.8		18		2		n.d.		2
	Tvc	5	1-3	2		0	1.5-31.3	9.7	14-18	16	0-220	74		n.d.	8-14	1
MIDDLE MIOCENE																
Monterey Formation	Tmc	6	1-18	9	0-6	1	18-45	32	18-23	20	0-238	55		n.d.	28-64	4
	Tml	15	1-17	6	0-6	2	10-38	21	14-30	22	0-78	8		n.d.	10-52	2
	Tm	54	2-72	10	0-23	4	3-45	22	11-48	19	0-160	18	0.06-0.10	0.08(9)	3-81	3
	Phosphatic beds[3]	70	3-69	20	3-626	93	7-195	63	15-63	26	0-268	25	0.13-17.11	3.6	20-468	14.
PLIOCENE																
Santa Margarita Formation. . .	Tsm	1		0		0.2		5		16		0		n.d		
Pancho Rico Formation (marine)	Tpd	2	3-13	8	3-5	2	8-10	9		16	0-92	46		n.d	25-32	2
	Tps	4	2-13	8	0-1	1	5-13	9	17-25	21	0-50	14		n.d	18-24	21
	Tpi	4	9-17	14	2-5	3	8-23	16	20-33	24	158-300	216	0.09-0.12	0.11(2)	21-76	4
	Tpo	38	2-21	8	0-4		8-38	15	12-30	21	0-63	21		n.d	16-64	2
	Phosphatic beds[3]	5	1-32	12	7-100	29	6-132	41	18-25	21	8-175	52	0.17-4.65	1.12	43-238	8
Unnamed unit (marine).	Tus	11	2-14	6	0-7	2	3-30	11	14-24	19	0-48	11		0.11(1)	9-37	2
PLEISTOCENE																
Paso Robles Formation.	QTc	1		4		1		20		28		70		n.d.		3
	QTt	1		3		0		5		15		0		n.d.		1
	QTp	13	0-15	6	0-2	1	8-38	19	15-25	20	0-63	11		0.11(1)	14-58	2

[1] Durham, 1964a, 1964b, 1966, 1970; Dibblee, 1971, 1972.

[2] Number in parentheses denotes number of samples analyzed for phosphorus.

[3] Phosphatic beds in Monterey and Pancho Rico Formations are not separately mapped.

[4] Abbreviations as used in Hart, E.W., 1966, Mines and mineral resources of Monterey County.

n.d. not determined.

Cadmium is present in anomalously high proportions in the ing City–San Ardo area, especially in the sediments derived om the Middle Miocene marine Monterey Formation. Cad-ium is also unusually high in the phosphatic beds; these beds e the main source of cadmium contamination in the stream diments and agricultural soils (Lockwood Loam Soil) of the ing City–San Ardo area.

Cadmium is the only hazardous element present in quantities at would threaten public health.

RECOMMENDATION

Because similar pockets of cadmium–contaminated phosphate ds may occur elsewhere, such phosphatic materials should be -evaluated before they are used as raw material for fertilizers.

ACKNOWLEDGMENTS

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APPENDIX A

Locations of Stream Sediment Samples

LAB. NO.	NAME OF MATERIAL	FIELD NO.	LOCATION	LATITUDE		LONGITUDE	
				DEG.	MIN.	DEG.	MIN.
209/72	STREAM SEDIMENT	72-M-001	PINE CANYON	36	8.23	121	13.62
210/72	STREAM SEDIMENT	72-M-002	BRONSTET CANYON	36	12.54	121	10.05
211/72	STREAM SEDIMENT	72-M-003	THOMPSON CANYON	36	10.79	121	13.62
212/72	STREAM SEDIMENT	72-M-004	HERBERT CANYON	36	12.15	121	11.85
213/72	STREAM SEDIMENT	72-M-005	ARROYO SECO ROAD	36	14.17	121	28.28
214/72	STREAM SEDIMENT	72-M-006	ARROYO SECO ROAD	36	15.01	121	25.65
215/72	STREAM SEDIMENT	72-M-007	PINEY CREEK	36	15.59	121	25.65
216/72	STREAM SEDIMENT	72-M-008	PALOMA CREEK	36	18.45	121	28.68
217/72	STREAM SEDIMENT	72-M-009	ARROYO SECO	36	15.76	121	23.85
218/72	STREAM SEDIMENT	72-M-010	ARROYO SECO	36	16.85	121	19.45
219/72	STREAM SEDIMENT	72-M-011	RELIZ CREEK	36	12.95	121	16.90
220/72	STREAM SEDIMENT	72-M-012	MONROE CANYON RD	36	10.95	121	15.10
221/72	STREAM SEDIMENT	72-M-013	PINE CANYON	36	10.84	121	9.12
222/72	STREAM SEDIMENT	72-M-014	GRANT PARAISO RD	36	23.66	121	19.45
223/72	STREAM SEDIMENT	72-M-015	PARAISO ROAD	36	20.07	121	21.40
224/72	STREAM SEDIMENT	72-M-016	FOOTHILL ROAD	36	23.16	121	22.12
225/72	STREAM SEDIMENT	72-M-017	EX MISSION SOLED	36	24.49	121	25.15
226/72	STREAM SEDIMENT	72-M-018	PARAJE DE SANCHEZ	36	26.49	121	27.47
227/72	STREAM SEDIMENT	72-M-019	PARAJE DE SANCHEZ	36	27.66	121	27.54
228/72	STREAM SEDIMENT	72-M-020	PARAJE DE SANCHEZ	36	28.62	121	29.33
229/72	STREAM SEDIMENT	72-M-021	NW SIERR DE SALNS	36	29.21	121	31.15
230/72	STREAM SEDIMENT	72-M-022	NW SIERR DE SALNS	36	29.62	121	30.45
231/72	STREAM SEDIMENT	72-M-023	SALINAS RIVER RD	36	30.62	121	31.00
232/72	STREAM SEDIMENT	72-M-024	LIMEKILN CREEK	36	30.74	121	32.20
233/72	STREAM SEDIMENT	72-M-025	LIMEKILN CREEK	36	31.16	121	31.52
234/72	STREAM SEDIMENT	72-M-026	LORIDON CANYON	36	1.93	121	4.52
235/72	STREAM SEDIMENT	72-M-027	MCCONNELL CANYON	36	1.80	121	3.30
236/72	STREAM SEDIMENT	72-M-028	BROADHURST CANYON	36	3.48	121	1.30
237/72	STREAM SEDIMENT	72-M-029	BROADHURST CANYON	36	3.75	121	1.20
238/72	STREAM SEDIMENT	72-M-030	BROADHURST CANYON	36	3.98	121	1.52
239/72	STREAM SEDIMENT	72-M-031	ESPINOSA CANYON	36	4.38	121	2.15
240/72	STREAM SEDIMENT	72-M-032	ESPINOSA CANYON	36	4.35	121	2.72
241/72	STREAM SEDIMENT	72-M-033	FELIZ CANYON	36	3.59	121	6.02
242/72	STREAM SEDIMENT	72-M-034	FELIZ CANYON	36	3.86	121	4.71
243/72	STREAM SEDIMENT	72-M-035	FELIZ CANYON	36	4.75	121	4.60
244/72	STREAM SEDIMENT	72-M-036	LOWE CANYON	36	9.88	120	56.50
245/72	STREAM SEDIMENT	72-M-037	HAMILTON CANYON	36	10.22	120	58.08
246/72	STREAM SEDIMENT	72-M-038	HAMILTON CREEK	36	10.27	120	57.25
247/72	STREAM SEDIMENT	72-M-039	LOWE CANYON	36	10.89	120	54.78
248/72	STREAM SEDIMENT	72-M-040	NATTRAS VALLEY	36	10.76	120	56.35
249/72	STREAM SEDIMENT	72-M-041	WILDHORSE CANYON	36	11.50	120	58.85
250/72	STREAM SEDIMENT	72-M-042	TOM VALLEY	36	12.06	120	56.41
251/72	STREAM SEDIMENT	72-M-043	WILDHORSE CANYON	36	11.47	120	57.40
252/72	STREAM SEDIMENT	72-M-044	SWEETWATER CANYON	36	13.59	121	1.58
253/72	STREAM SEDIMENT	72-M-045	BULL CANYON	36	14.57	121	2.11
254/72	STREAM SEDIMENT	72-M-046	SAN LORENZO CREEK	36	13.34	121	6.11
255/72	STREAM SEDIMENT	72-M-047	SAN LORENZO	36	14.66	121	5.64
256/72	STREAM SEDIMENT	72-M-048	LIANO GRANDE CAN	36	17.82	121	3.38
257/72	STREAM SEDIMENT	72-M-049	LIANO GRANDE CAN	36	16.66	121	6.29
258/72	STREAM SEDIMENT	72-M-050	AGUA GRANDE CAN	36	18.16	121	9.15
259/72	STREAM SEDIMENT	72-M-051	KING CITY ROAD	36	19.14	121	10.00
260/72	STREAM SEDIMENT	72-M-052	SAN CARLOS CANYON	36	20.28	121	11.18
261/72	STREAM SEDIMENT	72-M-053	CHALONE CREEK	36	21.27	121	11.90
262/72	STREAM SEDIMENT	72-M-054	CHALONE CREEK	36	21.24	121	12.40
263/72	STREAM SEDIMENT	72-M-055	CHALONE CREEK	36	21.83	121	11.85
264/72	STREAM SEDIMENT	72-M-056	METZ SOLEDAD ROAD	36	23.89	121	15.02
265/72	STREAM SEDIMENT	72-M-057	SHIRTTAIL GULCH	36	25.50	121	13.51
266/72	STREAM SEDIMENT	72-M-058	METZ SOLEDAD ROAD	36	25.42	121	16.50
267/72	STREAM SEDIMENT	72-M-059	STONEWALL CREEK	36	26.59	121	17.47
268/72	STREAM SEDIMENT	72-M-060	BRYANT CANYON	36	27.05	121	17.72
269/72	STREAM SEDIMENT	72-M-061	N SOLEDAD	36	27.05	121	18.70
270/72	STREAM SEDIMENT	72-M-062	N SOLEDAD	36	27.71	121	19.36
271/72	STREAM SEDIMENT	72-M-063	N SOLEDAD	36	28.80	121	20.30
272/72	STREAM SEDIMENT	72-M-064	HENRY SAND CANYON	36	30.78	121	20.62
273/72	STREAM SEDIMENT	72-M-065	SULLIVAN CANYON	36	31.32	121	21.37
274/72	STREAM SEDIMENT	72-M-066	MCCOY CREEK	36	31.46	121	22.08
275/72	STREAM SEDIMENT	72-M-067	JOHSON CREEK	36	32.22	121	24.02
276/72	STREAM SEDIMENT	72-M-068	CHUALAR O ZANJON	36	34.24	121	26.64
277/72	STREAM SEDIMENT	72-M-069	CHUALAR CREEK	36	36.16	121	25.66
279/72	STREAM SEDIMENT	72-M-071	SE EL ALISAL	36	38.20	121	31.00
280/72	STREAM SEDIMENT	72-M-072	SE EL ALISAL	36	38.95	121	32.10
281/72	STREAM SEDIMENT	72-M-073	E EL ALISAL	36	39.98	121	32.60
282/72	STREAM SEDIMENT	72-M-074	E SAUSAL	36	41.63	121	33.98
283/72	STREAM SEDIMENT	72-M-075	DUNN CANYON	36	42.14	121	32.20
284/72	STREAM SEDIMENT	72-M-076	E SAUSAL	36	42.75	121	13.65
285/72	STREAM SEDIMENT	72-M-077	E SAUSAL	36	42.66	121	33.36
286/72	STREAM SEDIMENT	72-M-078	NE SAUSAL	36	42.74	121	35.09
287/72	STREAM SEDIMENT	72-M-079	NATIVIDAD CREEK	36	43.14	121	35.41
288/72	STREAM SEDIMENT	72-M-080	NATIVIDAD CREEK	36	43.87	121	35.32
289/72	STREAM SEDIMENT	72-M-081	CACHAGUA CREEK	36	23.80	121	38.98
290/72	STREAM SEDIMENT	72-M-082	FINCH CREEK	36	23.44	121	35.66
291/72	STREAM SEDIMENT	72-M-083	TULARCITOS CREEK	36	25.29	121	36.85
292/72	STREAM SEDIMENT	72-M-084	TULARCITOS CREEK	36	26.73	121	40.35
293/72	STREAM SEDIMENT	72-M-085	TULARCITOS CREEK	36	27.25	121	41.90
294/72	STREAM SEDIMENT	72-M-086	CARMEL RIVER	36	28.22	121	42.95
295/72	STREAM SEDIMENT	72-M-087	CARMEL RIVER	36	28.47	121	43.75
296/72	STREAM SEDIMENT	72-M-088	GABILAN CREEK	36	46.38	121	36.08
297/72	STREAM SEDIMENT	72-M-089	GABILAN CREEK	36	46.83	121	34.98
298/72	STREAM SEDIMENT	72-M-090	GABILAN CREEK	36	46.35	121	35.25
299/72	STREAM SEDIMENT	72-M-091	MUD CREEK	36	47.03	121	35.45
300/72	STREAM SEDIMENT	72-M-092	MUD CREEK	36	47.14	121	35.29
301/72	STREAM SEDIMENT	72-M-093	CRAZY HORSE CAN	36	47.36	121	36.58
302/72	STREAM SEDIMENT	72-M-094	SAN MIGUEL CANYON	36	49.12	121	40.27
303/72	STREAM SEDIMENT	72-M-095	SALINAS RIVER	36	40.70	121	44.65
304/72	STREAM SEDIMENT	72-M-096	SALINAS RIVER	36	38.82	121	42.25
305/72	STREAM SEDIMENT	72-M-097	EL TORO	36	37.46	121	41.20
306/72	STREAM SEDIMENT	72-M-098	SALINAS RIVER	36	37.84	121	40.22
572/72	STREAM SEDIMENT	72-M-099	SALINAS RIVER	35	45.18	120	41.18
573/72	STREAM SEDIMENT	72-M-100	SALINAS RIVER	35	48.21	120	44.43
574/72	STREAM SEDIMENT	72-M-101	SALINAS RIVER	35	51.86	120	48.58
575/72	STREAM SEDIMENT	72-M-102	SAN ANTONIO RIVER	35	49.13	120	50.42
576/72	STREAM SEDIMENT	72-M-103	SAN ANTONIO RIVER	35	48.47	120	51.32
577/72	STREAM SEDIMENT	72-M-104	SALINAS RIVER	36	0.97	120	54.73
578/72	STREAM SEDIMENT	72-M-105	REDHEAD CANYON	36	3.13	120	54.14
579/72	STREAM SEDIMENT	72-M-106	JIM LAWSON GULCH	36	2.70	120	54.48
580/72	STREAM SEDIMENT	72-M-107	PINE CREEK	36	5.97	120	52.64
581/72	STREAM SEDIMENT	72-M-108	PINE CREEK	36	5.50	120	53.15
582/72	STREAM SEDIMENT	72-M-109	PINE CREEK	36	4.55	120	54.85
583/72	STREAM SEDIMENT	72-M-110	SALINAS RIVER	36	7.00	121	1.65
584/72	STREAM SEDIMENT	72-M-111	SALINAS RIVER	36	12.20	121	8.35
585/72	STREAM SEDIMENT	72-M-112	SALINAS RIVER	36	10.44	121	6.24
586/72	STREAM SEDIMENT	72-M-113	QUINADO CANYON	36	6.50	121	7.93
587/72	STREAM SEDIMENT	72-M-114	QUINADO CANYON	36	5.05	121	10.42
588/72	STREAM SEDIMENT	72-M-115	JOLON ROAD	36	4.13	121	11.04
589/72	STREAM SEDIMENT	72-M-116	SULPHUR SPRING CR	36	2.67	121	11.58
590/72	STREAM SEDIMENT	72-M-117	SULPHUR SPRING CR	36	2.56	121	12.99
591/72	STREAM SEDIMENT	72-M-118	SULPHUR SPRING CR	36	1.96	121	13.87
592/72	STREAM SEDIMENT	72-M-119	JOLON VALLEY	36	0.45	121	10.80
593/72	STREAM SEDIMENT	72-M-120	NACIMIENTO RIVER	35	48.81	120	45.46
594/72	STREAM SEDIMENT	72-M-121	GARRISERRE CANYON	36	1.15	120	56.90
595/72	STREAM SEDIMENT	72-M-122	S SAN BENITO	36	6.37	121	3.02
596/72	STREAM SEDIMENT	72-M-123	PANCHO CREEK	36	1.14	120	53.23
597/72	STREAM SEDIMENT	72-M-124	PANCHO RICO CREEK	36	2.66	120	49.68
598/72	STREAM SEDIMENT	72-M-125	PINE CREEK	36	9.14	120	51.95
599/72	STREAM SEDIMENT	72-M-126	SAN LORENZO CREEK	36	11.65	120	50.11
600/72	STREAM SEDIMENT	72-M-127	SAN LORENZO CREEK	36	11.85	120	50.10
601/72	STREAM SEDIMENT	72-M-128	SAN LORENZO CREEK	36	12.54	120	51.98
602/72	STREAM SEDIMENT	72-M-129	SAN LORENZO CREEK	36	11.17	120	48.88
603/72	STREAM SEDIMENT	72-M-130	SAN LORENZO CREEK	36	10.40	120	47.47
604/72	STREAM SEDIMENT	72-M-131	SAN LORENZO CREEK	36	10.30	120	47.35
605/72	STREAM SEDIMENT	72-M-132	WILDHORSE CANYON	36	11.48	121	2.40
606/72	STREAM SEDIMENT	72-M-133	WILDHORSE CANYON	36	11.99	121	0.65
607/72	STREAM SEDIMENT	72-M-134	MONROE CREEK	36	15.55	121	12.30
608/72	STREAM SEDIMENT	72-M-135	POSA LOS OSITOS	36	17.54	121	11.38
609/72	STREAM SEDIMENT	72-M-136	SALINAS RIVER	36	20.36	121	12.15
610/72	STREAM SEDIMENT	72-M-137	RELIZ CANYON	36	16.42	121	18.01
611/72	STREAM SEDIMENT	72-M-138	ARROYO SECO	36	15.65	121	22.35
612/72	STREAM SEDIMENT	72-M-139	PALOMA CREEK	36	16.53	121	27.10
614/72	STREAM SEDIMENT	72-M-141	PALOMA CREEK	36	17.68	121	28.08
615/72	STREAM SEDIMENT	72-M-142	JMS ARROYO SECO R	36	20.64	121	31.50
616/72	STREAM SEDIMENT	72-M-143	PALOMA CREEK	36	20.46	121	30.05
617/72	STREAM SEDIMENT	72-M-144	THORNE ROAD	36	19.34	121	17.54
618/72	STREAM SEDIMENT	72-M-145	SALINAS RIVER	36	24.62	121	19.00
619/72	STREAM SEDIMENT	72-M-146	SALINAS RIVER	36	29.25	120	0.0
620/72	STREAM SEDIMENT	72-M-147	CHUALAR RIVER RD	36	33.30	121	32.83
621/72	STREAM SEDIMENT	72-M-148	PARKER CANYON	36	34.38	121	36.43
622/72	STREAM SEDIMENT	72-M-149	PARKER CANYON	36	34.68	121	36.37
623/72	STREAM SEDIMENT	72-M-150	SALINAS RIVER RD	36	35.52	121	37.34
624/72	STREAM SEDIMENT	72-M-151	PINE CANYON ROAD	36	34.87	121	37.81
625/72	STREAM SEDIMENT	72-M-152	SALINAS RIVER	36	36.75	121	39.33
626/72	STREAM SEDIMENT	72-M-153	SALINAS RIVER	36	36.78	121	39.13
627/72	STREAM SEDIMENT	72-M-154	SAN BENANCIO ROAD	36	34.76	121	43.15
628/72	STREAM SEDIMENT	72-M-155	SAN BENANCIO GLCH	36	33.02	121	40.96
629/72	STREAM SEDIMENT	72-M-156	CORRAL TIERRA RD	36	33.38	121	43.85
630/72	STREAM SEDIMENT	72-M-157	WATSON CREEK	36	32.52	121	43.48
631/72	STREAM SEDIMENT	72-M-158	CORRAL TIERRA VAL	36	31.51	121	41.08
632/72	STREAM SEDIMENT	72-M-159	CORRAL TIERRA VAL	36	31.83	121	40.25
633/72	STREAM SEDIMENT	72-M-160	WATSON CREEK	36	32.13	121	43.33
634/72	STREAM SEDIMENT	72-M-161	CORRAL TIERRA RD	36	32.97	121	43.95
635/72	STREAM SEDIMENT	72-M-162	CALERA CANYON	36	32.22	121	44.25
636/72	STREAM SEDIMENT	72-M-163	EL TORO ROAD	36	33.45	121	44.93
637/72	STREAM SEDIMENT	72-M-164	ROUTE 68 CAL	36	34.44	121	49.25
638/72	STREAM SEDIMENT	72-M-165	CONJ CAL 68&218	36	34.93	121	49.73
639/72	STREAM SEDIMENT	72-M-166	PAJARO RIVER	36	53.06	121	46.21
640/72	STREAM SEDIMENT	72-M-167	PAJARO RIVER	36	54.33	121	40.67
641/72	STREAM SEDIMENT	72-M-168	MAHER ROAD	36	51.51	121	41.62
642/72	STREAM SEDIMENT	72-M-169	HALL ROAD	36	49.53	121	43.03
643/72	STREAM SEDIMENT	72-M-170	STRAWBERRY CANYON	36	49.94	121	43.48
644/72	STREAM SEDIMENT	72-M-171	SWISS CANYON	36	48.90	121	43.08
645/72	STREAM SEDIMENT	72-M-172	LONG CANYON	36	48.76	121	42.15
646/72	STREAM SEDIMENT	72-M-173	PARADISE CANYON	36	47.94	121	41.87
647/72	STREAM SEDIMENT	72-M-174	CASTROVILLE BLVD	36	47.72	121	43.22
648/72	STREAM SEDIMENT	72-M-175	ELKHORN ROAD	36	47.10	121	42.76
649/72	STREAM SEDIMENT	72-M-176	EAST OF ELKHORNRD	36	48.05	121	38.45
650/72	STREAM SEDIMENT	72-M-177	VIERRA CANYON	36	48.05	121	38.45
651/72	STREAM SEDIMENT	72-M-178	CANADA D L CARREN	36	51.75	121	38.94
652/72	STREAM SEDIMENT	72-M-179	CANADA D L CARPEN	36	51.31	121	38.86
653/72	STREAM SEDIMENT	72-M-180	CANADA D L CARPEN	36	46.66	121	39.52
654/72	STREAM SEDIMENT	72-M-181	PESANTE CANYON	36	46.82	121	38.42
655/72	STREAM SEDIMENT	72-M-182	PESANTE CANYON	36	46.73	121	39.03
656/72	STREAM SEDIMENT	72-M-183	PESANTE CANYON	36	46.28	121	39.97
657/72	STREAM SEDIMENT	72-M-184	PESANTE CANYON	36	35.32	121	36.15
658/72	STREAM SEDIMENT	72-M-185	SALINAS RIVER RD	36	33.81	121	34.05
659/72	STREAM SEDIMENT	72-M-186	GUAD LLANIT L ORR	36	33.32	121	34.80
660/72	STREAM SEDIMENT	72-M-187	GUAD LLANIT L ORR	36	33.42	121	33.93
661/72	STREAM SEDIMENT	72-M-188	GUAD LLANIT L ORR	36	32.35	121	33.33
662/72	STREAM SEDIMENT	72-M-189	GUAD LLANIT L ORR	36	21.66	121	34.77
663/72	STREAM SEDIMENT	72-M-190	JAMES CREEK	36	22.08	121	35.37
664/72	STREAM SEDIMENT	72-M-191	JAMES CREEK	36	23.64	121	34.95
665/72	STREAM SEDIMENT	72-M-192	CACHAGUA CREEK	36	23.76	121	34.25
666/72	STREAM SEDIMENT	72-M-193	CACHAGUA CREEK	36	20.84	121	32.50
667/72	STREAM SEDIMENT	72-M-194	FINCH CREEK	36	23.76	121	39.70
668/72	STREAM SEDIMENT	72-M-195	CARMEL RIVER	36	27.28	121	42.93
669/72	STREAM SEDIMENT	72-M-196	CARMEL RIVER	36	29.35	121	44.83
670/72	STREAM SEDIMENT	72-M-197	CARMEL RIVER	36	31.20	121	48.42
671/72	STREAM SEDIMENT	72-M-198	CARMEL RIVER	36	31.58	121	49.89
672/72	STREAM SEDIMENT	72-M-199	CARMEL RIVER	36	32.35	121	52.75
673/72	STREAM SEDIMENT	72-M-200	CARMEL RIVER	36	32.25	121	54.78
674/72	STREAM SEDIMENT	72-M-201	CARMEL RIVER	36	32.25	121	54.78

Location of Bedrock Samples
and Some Stream Sediment Samples

LAH. NO.	NAME OF MATERIAL	FIELO NO.	LOCATION	LATITUDE OEG.	MIN.	LONGITUOE DEG.	MIN.	FORMATION
93/73	SHALE	73-M-01A	W SAN LUCAS	36	5.04	121	2.79	MONTFREY FORM.TM
94/73	SHALE	73-M-01B	W SAN LUCAS	36	4.94	121	2.72	MONTFREY FORM.TM
95/73	MUDSTONE	73-M-01C	W SAN LUCAS	36	4.95	121	2.84	MONTFREY FORM.TM
96/73	STREAM SEDIMENT	73-M-01D	W SAN LUCAS	36	4.88	121	2.76	STREAM SEOIMENT
97/73	SHALE	73-M-02A	LORIDON CANYON	36	2.37	121	4.69	FAULT ZONE SAMPLE
98/73	SHALE	73-M-02B	LORIOON CANYON	36	2.34	121	4.66	FAULT ZONE SAMPLE
99/73	SHALE	73-M-03A	LORID S LUCAS CAN	36	1.43	121	4.07	FAULT ZONE SAMPLF
100/73	MUDSTONE	73-M-03B	SAN LUCAS CANYON	36	0.13	121	3.97	MONTFREY FORM.TM
101/73	MUDSTONF	73-M-03C	SAN LUCAS CANYON	36	0.13	121	3.97	MONT.FORM.PHOSPHATIC
102/73	MUDSTONE	73-M-04A	QUINADO CANYON RO	36	7.18	121	7.86	MONT.FORM.PHOSPHATIC
103/73	SHALE	73-M-04B	QUINADO CANYON RO	36	7.18	121	7.86	MONTFREY FORM.TM
104/73	MUDSTONE	73-M-05A	QUINADO CANYON RO	36	5.17	121	10.55	MONTFREY FORM.TM
105/73	MUDSTONE	73-M-05B	QUINADO CANYON RD	36	5.17	121	10.55	MONTFREY FORM.TM
106/73	MUDSTONE	73-M-06A	QUINADO CANYON RO	36	4.20	121	11.04	MONTFREY FORM.TM
107/73	GRAVEL & SANO	73-M-06B	SULRHUR SPRING RO	36	2.64	121	12.43	PASO ROBLES FORM.QTP
108/73	SANOSTONE	73-M-07A	SULPHUR SPRING RD	36	2.67	121	12.43	PASO ROBLES FORM.QTC
109/73	SANDSTONE	73-M-07B	SULPHUR SRRING RO	36	2.53	121	13.08	PANCHO RICO FM.PHOSP
110/73	PORCELANITE	73-M-08A	SULPHUR SPRING RO	36	2.46	121	13.39	MONTFREY FORM.TM
111/73	SHALF	73-M-08B	SULPHUR SPRING RD	36	2.46	121	13.39	MONT.FORM.RHOSPHATIC
112/73	MUDSTONE	73-M-08C	SULPHUR SPRING RO	36	2.46	121	13.39	MONT.FORM.PHOSPHATIC
113/73	SANDSTONE	73-M-09A	SULPHUR SRRING RO	36	2.10	121	13.65	PANCHO RICO FORM.TRS
114/73	MUDSTONE	73-M-09M	ESPINOSA CANYON	36	4.50	121	3.60	MONTEREY FORM.TM
115/73	MUDSTONE	73-M-10A	FELIZ CANYON	36	3.66	121	4.54	MONT.FORM.PHOSPHATIC
116/73	MUDSTONE	73-M-10M	FELIZ CANYON	36	3.66	121	4.54	MONT.FORM.PHOSPHATIC
117/73	MUDSTONE	73-M-11A	FELIZ CANYON	36	3.70	121	6.10	MONTFREY FORM.TM
118/73	MUDSTONE	73-M-11B	FELIZ CANYON	36	4.37	121	4.63	MONT.FORM.PHOSPHATIC
119/73	MUDSTONE	73-M-12A	FELIZ CANYON	36	4.75	121	4.72	MONTFREY FORM.TM
120/73	SHALE	73-M-12B	FELIZ CANYON	36	4.75	121	4.72	MONTFREY FORM.TM
121/73	MUOSTONE	73-M-12C	FELIZ CANYON	36	4.75	121	4.72	MONT.FORM.PHOSPHATIC
122/73	SANOSTONE	73-M-13A	W SAN LUCAS	36	5.44	121	3.41	MONTFREY FORM.TM
123/73	SANDSTONE	73-7-14A	PINE CANYON RO	36	10.36	121	9.28	PANCHO RICO FORM.TRO
124/73	MUDSTONE	73-M-14B	PINE CANYON RO	36	9.88	121	9.69	MONTFREY FORM.TM
125/73	MUDSTONE	73-M-15A	PINE CANYON	36	9.38	121	10.25	MONTEREY FORM.TM
126/73	MUDSTONE	73-M-15B	RINE CANYON	36	9.38	121	10.25	MONTFREY FORM.TM
127/73	MUDSTONE	73-M-16A	PINE CANYON	36	9.14	121	11.19	MONTEREY FORM.TM

LAB. NO.	NAME OF MATERIAL	FIELD NO.	LOCATION	LATITUDE OFG.	MIN.	LONGITUDE DEG.	MIN.	FORMATION
128/73	MUDSTONE	73-M-16B	PINE CANYON RO	36	8.73	121	12.10	MONT.FORM.PHOSPHATIC
129/73	MUDSTONE	73-M-17A	PINE CANYON RO	36	8.73	121	12.10	MONT.FORM.PHOSPHATIC
130/73	MUDSTONE	73-M-17B	PINE CANYON RD	36	8.73	121	12.10	MONTFREY FORM.TM
131/73	CLAY SEAM	73-M-17C	PINE CANYON RO	36	8.73	121	12.10	MONTFREY FORM.TM
132/73	SHALF	73-M-18A	PINE CANYON	36	8.38	121	13.09	MONTEREY FORM.TML
133/73	SHALE	73-M-18B	PINE CANYON	36	8.38	121	13.09	MONTFREY FORM.TML
134/73	SHALE	73-M-18C	PINE CANYON	36	8.38	121	13.09	MONTFREY FORM.TMC
135/73	CLAY SHALF	73-M-18D	PINE CANYON	36	8.38	121	13.09	MONTFREY FORM.TMC
136/73	CLAY SHALE	73-M-18E	PINF CANYON	36	8.38	121	13.09	MONTEREY FORM.TMC
137/73	SANOSTONE	73-M-19A	PINE CANYON RO	36	8.30	121	13.34	VAQ.SANDSTONE TVQ
138/73	SANDSTONE	73-M-19B	PINE CANYON RO	36	8.14	121	13.58	BERRY FORMATION TBE
139/73	SANDSTONE	73-M-20A	PINE CANYON	36	8.10	121	14.04	THE ROCKS-TR.TL.TJ
140/73	SANOSTONE	73-M-20B	BRENSTETT CANYON	36	12.33	121	10.50	PASO ROBLES FORM.OTP
141/73	MUDSTONE	73-M-21A	BRENSTETT CANYON	36	11.77	121	11.28	MONTFREY FORM.TM
142/73	SANDSTONF	73-M-21B	BRENSTETT CANYON	36	12.16	121	10.73	PANCHO RICO FM.PHOSP
143/73	STREAM SEDIMENT	73-M-22A	HERBERT CANYON	36	11.94	121	12.16	STREAM SEOIMENT
144/73	MUDSTONE	73-M-22B	HERBERT CANYON	36	11.44	121	12.29	MONTFREY FORM.TM
145/73	MUDSTONE	73-M-23A	THUMPSON CANYON	36	12.78	121	12.40	MONT.FORM.PHOSPHATIC
146/73	MUDSTONE	73-M-23B	THOMRSON CANYON	36	11.54	121	13.48	MONTEREY FORM.TM
147/73	MUDSTONE	73-M-24A	THOMRSON CANYON	36	10.53	121	13.72	MONT.FORM.PHOSPHATIC
148/73	MUDSTONE	73-M-24B	THOMRSON CANYON	36	10.53	121	13.72	MONTFREY FORM.TM
149/73	MUDSTONE	73-M-24C	THOMRSON CANYON	36	10.53	121	13.72	MONTFREY FORM.TM
150/73	MUDSTONE	73-M-24D	THUMPSON CANYON	36	10.53	121	13.72	MONTFREY FORM.TM
151/73	MUDSTONE	73-M-25A	MONROE CANYON RO	36	10.35	121	15.50	MONTFREY FORM.TM
152/73	MUDSTONE	73-M-25B	MONRUE CANYON RD	36	10.15	121	15.60	MONTFREY FORM.TM
153/73	MUDSTONE	73-M-26A	MONROE CANYON RO	36	12.82	121	15.70	MONT.FORM.PHOSPHATIC
154/73	SANDSTONE	73-M-26B	RELIZ CANYON RO	36	14.18	121	17.00	PANCHO PICO FORM.TPS
155/73	CLAY SEAM	73-M-27A	RELIZ CANYON RD	36	13.88	121	16.90	MONT.FORM.PHOSPHATIC
156/73	MUDSTONE	73-M-27M	RELIZ CANYON RO	36	13.88	121	16.90	MONT.FORM.PHOSPHATIC
157/73	MUDSTONE	73-M-28A	RELIZ CANYON RD	36	12.67	121	16.74	MONTFREY FORM.TM
158/73	MUDSTONE	73-M-28M	RELIZ CANYON RD	36	11.63	121	16.70	MONTFRFY FORM.TML
159/73	PHOSPHA-PELLETS	73-M-29A	RELIZ CANYON RD	36	11.67	121	16.65	MONT.FORM.PHOSPHATIC
160/73	RHOSPHETIC PELL	73-M-29B	RELIZ CANYON RD	36	11.67	121	16.65	MONT.FORM.RHOSPHATIC
161/73	SANDSTONE	73-M-30A	RELIZ CANYON RD	36	14.84	121	17.19	PASO ROBLES FORM.QTP
162/73	MUDSTONE	73-M-30B	ARROYO SECO ROAO	36	16.84	121	19.43	MONT.FORM.RHOSPHATIC

LAB. NO.	NAME OF MATERIAL	FIELO NO.	LOCATION	LATITUDE DFG.	MIN.	LONGITUOE OEG.	MIN.	FORMATION
163/73	MUDSTONF	73-M-31A	ARROYO SECO ROAO	36	16.00	121	21.53	MONT.FORM.PHOSPHATIC
164/73	MUDSTONE	73-M-31B	ARROYO SECO ROAO	36	16.30	121	23.53	MONTFREY FORM.TM
165/73	SHALE	73-M-32A	JAMESBURG ROAD	36	15.50	121	25.43	MONTEREY FORM.TM
166/73	MUOSTONE	73-M-32B	JAMESBURG ROAO	36	15.50	121	25.43	MONTEREY FORM.TM
167/73	PHOSPHATIC PELL	73-M-32C	JAMESBURG ROAO	36	15.50	121	25.43	MONT.FORM.PHOSPHATIC
168/73	PHOSPHATIC RELL	73-M-32D	JAMESBURG ROAO	36	15.50	121	25.43	MONT.FORM.PHOSPHATIC
169/73	MUOSTONE	73-M-33A	JAMESBURG ROAO	36	16.06	121	26.09	MONTEREY FORM.TM
170/73	MUOSTONE	73-M-33B	JAMESBURG ROAO	36	16.52	121	26.97	MONT.FORM.PHOSPHATIC
171/73	MUDSTONE	73-M-34A	JAMESBURG ROAO	36	16.83	121	27.21	MONT.FORM.PHOSPHATIC
172/73	FORAM LIMESTONE	73-M-34B	JAMESBURG ROAO	36	18.00	121	28.39	MONTEREY FORM.TML
173/73	FORAM LIMESTONE	73-M-35A	JAMESBURG ROAO	36	18.00	121	28.39	MONT.FORM.PHOSPHATIC
174/73	GRANODIORITE	73-M-36A	JAMESBURG ROAD	36	19.22	121	29.30	GRANIT.GR.GRD.GOD.GB
175/73	MUDSTONE	73-M-13B	W SAN LUCAS	36	5.44	121	3.41	MONTEREY FORM.TM
176/73	SANOSTONE	73-M 35B	W INDIAN CRFEK	35	28.52	120	23.58	SANTA MAGARITA SS.
177/73	SANDSTONE	73-M 36B	W INDIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC
178/73	MUDSTONE	73-M 37A	W INOIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC
179/73	MUDSTONE	73-M 37B	QUAIL WATER CREEK	35	28.78	120	24.94	MONT.FORM.RHOSRHATIC
180/73	RORCFLANITE	73-M 37C	W INDIAN CREEK	35	28.48	120	23.54	MONTFREY FORM.TM
181/73	CLAY SEAM	73-M 37D	W INOIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC
182/73	DIATOMITE	73-M-38A	WILOW CREEK ROAO	35	36.95	120	50.88	MONT.FORM.PHOSPHATIC
183/73	LIMESTONE	73-M-38B	WILOW CREEK ROAO	35	36.95	120	50.88	MONTFREY FORM.TM
184/73	OIATOMITE	73-M 39A	SUMMIT CANYON	35	35.93	120	48.75	MONTEREY FORM.TM
185/73	SANOSTONE	73-M 39B	SAN ARDO BEF RCRO	35	52.20	120	50.12	PASO ROBLES FORM.QTP
186/73	SANDSTONE	73-M-39C	SAN AROO BEE RCRO	35	52.20	120	50.12	PASO ROBLES FORM.OTP
187/73	SANDSTONE	73-M-40A	SAN AROO BEE RCRO	35	48.56	120	51.35	UNNAMEO UNIT-MAR.TUS
188/73	OIATOMITE	73-M-40B	SAN AROO BEE RCRO	35	48.54	120	51.43	PANCHO RICO FM.PHOSP
189/73	MUDSTONE	73-M 41A	S SULPHUR CANYON	35	46.58	120	53.36	MONTFREY FORM.TML
190/73	MUDSTONE	73-M 41B	S SULPHUR CANYON	35	46.58	120	53.36	MONTFREY FORM.TML
191/73	LIMESTONE	73-M 41C	S SULPHUR CANYON	35	46.58	120	53.36	MONTEREY FORM.TML
192/73	CLAY SHALE	73-M-42A	NACIMIENTO DAM	35	45.57	120	53.01	MONTEREY FORM.TMC
193/73	TAR SANOSTONE	73-M-42B	SAN AROD BEE RCRD	35	47.60	120	51.84	PASO ROBLES FORM.QTT
194/73	SANOSTONE	73-M 43A	SAN AROO BEE RCRO	35	47.60	120	51.84	MONTFREY FORM.TM
195/73	MUOSTONE	73-M-43B	SAN AROO BEE RCRO	35	47.60	120	51.84	MONTEREY FORM.TM
196/73	MUOSTONE	73-M-43C	SAN AROO BEE RCRO	35	47.60	120	51.84	MONTEREY FORM.TM
197/73	MUDSTONE	73-M-44A	JOLON RO	35	53.92	120	56.89	MONTEREY FORM.TM

LAB. NO.	NAME OF MATERIAL	FIELO NO.	LOCATION	LATITUDE OEG.	MIN.	LONGITUOE DEG.	MIN.	FORMATION
198/73	STREAM SEOIMENT	73-M-44B	HAMES CREEK	35	52.60	120	53.35	STREAM SEOIMENT
199/73	STREAM SEOIMENT	73-M-45A	JOLON RO	35	53.53	120	55.82	STRFAM SEOIMENT
200/73	STREAM SEDIMENT	73-M-45B	HAMES CREEK	35	54.48	120	56.07	STREAM SEOIMENT
201/73	MUDSTONE	73-M-46A	HAMES VALLEY RO	35	55.36	120	56.52	MONTFREY FORM.TM
202/73	MUOSTONE	73-M-46B	HAMES VALLEY RO	35	56.08	120	57.00	MONTFREY FORM.TM
203/73	STREAM SEDIMENT	73-M-47A	HAMES CREEK	35	56.25	120	57.00	STREAM SEOIMENT
204/73	MUDSTONE	73-M-47B	HAMES VALLEY RO	35	56.77	120	57.46	MONTEREY FORM.TM
205/73	STREAM SEDIMENT	73-M-48A	HAMES CREEK	35	55.62	120	56.50	STREAM SEOIMENT
206/73	MUDSTONE	73-M-48B	JOLON ROAO	35	54.25	120	58.10	MONT.FORM.PHOSPHATIC
207/73	SANOSTONE	73-M-49A	JOLON RO	35	54.38	120	59.51	PASO ROBLES FORM.QTP
208/73	CLAY	73-M-49B	JOLON RO	35	54.38	120	59.51	PASO ROBLES FORM.QTC
209/73	SANOSTONE	73-M-50A	W SWATN VALLEY	35	54.24	120	53.80	UNNAMEO UNIT-MAR.TUS
210/73	OIATOMITE	73-M-50B	W SWATN VALLEY	35	54.56	120	53.95	PANCHO RICO FORM.TPO
211/73	MUOSTONE	73-M-51A	NW SWATN VALLEY	35	55.62	120	54.44	MONTEREY FORM.TM
212/73	MUDSTONE	73-M-51B	US 101 HIGHWAY	35	57.42	120	52.92	MONTEREY FORM.TM
213/73	SANDSTONE	73-M-52A	US 101 HIGHWAY	35	57.37	120	52.88	PANCHO RICO FORM.TPO
214/73	SANDSTONE	73-M-52B	US 101 HIGHWAY	35	57.35	120	52.85	PANCHO RICO FORM.TRO
215/73	SANOSTONE	73-M-53A	W US 101 HIGHWAY	35	58.28	120	53.90	UNNAMEO UNIT-MAR.TUS
216/73	OIATOMITE	73-M 53B	W US 101 HIGHWAY	35	58.22	120	53.93	PANCHO RICO FORM.TPO
217/73	LIMESTONE	73-M-54A	LOS LOBOS SPR RD	35	57.92	120	53.42	MONTEREY FORM.TM
218/73	SANDY MUOSTONE	73-M-54B	LOS LOBOS SPR RO	35	57.92	120	53.42	MONTEREY FORM.TM
219/73	MUDSTONE	73-M-55A	LOS LOBOS SPR RO	35	57.74	120	55.47	MONT.FORM.PHOSPHATIC
220/73	MUOSTONE	73-M-56A	RANCHO RICO ROAO	36	2.66	120	49.36	PANCHO RICO FORM.TPO
221/73	MUOSTONE	73-M-55B	PANCHO RICO ROAO	36	4.08	120	46.32	PANCHO RICO FORM.TPO
222/73	SANOSTONE	73-M-55C	PANCHO RICO ROAO	36	4.08	120	46.32	PANCHO RICO FORM.TPS
223/73	SANOSTONE	73-M-56B	PANCHO RICO CREEK	36	1.63	120	51.29	UNNAMEO UNIT-MAR.TUS
224/73	SANOSTONE	73-M-57A	PANCHO RICO CREEK	36	1.63	120	51.29	UNNAMEO UNIT-MAR.TUS
225/73	SANOSTONE	73-M-57B	PANCHO RICO CREEK	36	1.63	120	51.29	UNNAMED UNIT-MAR.TUS
226/73	MUDSTONE	73-M-58A	PINE VALLEY ROAD	36	5.94	120	52.78	PANCHO RICO FORM.TPO
227/73	MUDSTONE	73-M-58B	PINE VALLEY ROAO	36	5.34	120	53.87	RANCHO RICO FORM.TPO
228/73	MUOSTONE	73-M-59A	PINE VALLEY ROAD	36	6.87	120	52.44	RANCHO RICO FORM.TPO
229/73	MUDSTONE	73-M-59B	PINE VALLEY ROAO	36	9.46	120	51.85	PANCHO RICO FORM.TPO
230/73	OIATOM.MUOSTONE	73-M-60A	ROUTE 198 CA.	36	9.96	120	52.33	PANCHO RICO FORM.TPO
231/73	OIATOM.MUDSTONE	73-M-60B	ROUTE 198 CA.	36	9.50	120	54.33	PANCHO RICO FORM.TPO
232/73	SANDSTONE	73-M-61A	CA ROUTE 198	36	8.97	120	56.97	PANCHO RICO FORM.TPO

APPENDIX B (continued)

Location of Bedrock Samples and Some Stream Sediment Samples

LAB. NO.	NAME OF MATERIAL	FIELD NO.	LOCATION	LATITUDE DEG.	MIN.	LONGITUDE DEG.	MIN.	FORMATION
233/73	MUDSTONE	73-M-61B	LOWE CANYON	36	9.86	120	56.29	PANCHO RICO FORM.TPR
234/73	MUDSTONE	73-M-62A	LONG NATTR VALLEY	36	9.97	120	57.34	PANCHO RICO FORM.TPR
235/73	MUDSTONE	73-M-62B	LONG NATTR VALLEY	36	10.35	120	56.24	PANCHO RICO FORM.TPR
236/73	SANDSTONE	73-M-63A	LONG NATTR VALLEY	31	10.49	120	56.75	PASO ROBLES FORM.QTP
237/73	SANDSTONE	73-M-63B	LONG NATTR VALLEY	36	10.24	120	57.35	PASO ROBLES FORM.QTP
238/73	SANDSTONE	73-M-64A	LONG NATTR VALLEY	36	10.32	120	57.92	PASO ROBLES FORM.QTP
239/73	MUDSTONE	73-M-64B	LONG NATTR VALLEY	36	10.58	120	57.21	PANCHO RICO FORM.TPR
240/73	SANDY MUDSTONE	73-M-65A	LONG NATTR VALLEY	36	10.72	120	56.37	PANCHO RICO FM.PHOSP
241/73	CONGLOMERATE	73-M-65B	LONG NATTR VALLEY	36	10.68	120	55.12	PASO ROBLES FORM.QTP
242/73	SANDY MUDSTONE	73-M-66A	LONG NATTR VALLEY	36	10.83	120	54.58	PANCHO RICO FORM.TPR
243/73	CLAYEY SANDSTON	73-M 66B	NATTRAS VALLEY	36	11.35	120	54.45	PANCHO RICO FORM.TPR
244/73	DIATOM.MUDSTONE	73-M 67A	NATTRAS VALLEY	36	11.62	120	54.55	PANCHO RICO FORM.TPR
245/73	DIATOM.MUDSTONE	73-M 67B	NATTRAS VALLEY	36	11.37	120	56.06	PANCHO RICO FORM.TPR
246/73	MUDSTONE	73-M 68A	LONG NATTR VALLEY	36	11.04	120	56.65	PANCHO RICO FORM.TPR
247/73	MUDSTONE	73-M-68B	WILD HORSE FREERD	36	11.34	121	2.70	PANCHO RICO FORM.TPR
248/73	MUDSTONE	73-M-69A	WILD HORSE CAN RD	36	11.48	120	58.85	PANCHO RICO FORM.TPR
249/73	DIATOMITE	73-M-69B	TOM VALLEY	36	12.06	120	70.16	PANCHO RICO FORM.TPR
250/73	DIATOMITE	73-M-70A	TOM VL WILD HORSE	36	11.61	120	57.96	PANCHO RICO FORM.TPR
251/73	SANDSTONE	73-M-70B	FREEMAN FLAT ROAD	36	9.23	121	0.84	PASO ROBLES FORM.QTP
252/73	SANDSTONE	73-M-71A	LONG VALLEY ROAD	36	8.30	121	0.72	UNNAMED UNIT-MAR.TUS
253/73	MUDSTONE	73-M-71B	WILD HOR SWEETCAN	36	12.35	121	3.32	PANCHO RICO FORM.TPR
254/73	MUDSTONE	73-M-72A	WILD HOR SWEETCAN	36	12.35	121	3.32	PANCHO RICO FORM.TPR
255/73	MUDSTONE	73-M-72B	LONOAK ROAD	36	13.62	121	3.72	PANCHO RICO FORM.TPR
256/73	MUDSTONE	73-M-73A	LONOAK ROAD	36	13.62	121	3.72	PANCHO RICO FORM.TPR
257/73	MUDSTONE	73-M-73B	LONOAK ROAD	36	13.83	121	3.04	PANCHO RICO FORM.TPS
258/73	MUDSTONE	73-M-74A	LONOAK ROAD	36	14.76	121	1.97	PANCHO RICO FORM.TPR
259/73	MUDSTONE	73-M-74B	LONOAK ROAD	36	14.87	121	1.07	PANCHO RICO FORM.TPR
260/73	MUDSTONE	73-M-75A	GRNT AROYO SEC RD	36	16.78	121	19.25	MONTEREY FORM.TM
261/73	SANDSTONE	73-M-75B	GRNT AROYO SEC RD	36	16.68	121	19.00	UNNAMED UNIT-MAR.TUS
262/73	SANDSTONE	73-M-76A	PARAISO SPRING RD	36	20.12	121	21.77	BERRY FORMATION TBE
263/73	SANDSTONE	73-M-76B	BITTERWATER ROAD	36	15.57	121	5.10	UNNAMED UNIT-MAR.TUS
264/73	GRANITIC-REGMAT	73-M-77A	BITTERWATER ROAD	36	16.19	121	4.24	GRANIT.GR.GRD.GQD.GB
265/73	GRANITIC ROCK	73-M-77B	BITTERWATER ROAD	36	16.19	121	4.24	GRANIT.GR.GRD.GQD.GB
266/73	MUDSTONE	73-M-78A	BITTERWATER ROAD	36	16.50	121	3.94	PANCHO RICO FORM.TPR
267/73	MUDSTONE	73-M-78B	BITTERWATER ROAD	36	19.00	121	2.00	PANCHO RICO FORM.TPR

LAB. NO.	NAME OF MATERIAL	FIELD NO.	LOCATION	LATITUDE DEG.	MIN.	LONGITUDE DEG.	MIN.	FORMATION
268/73	SANDSTONE	73-M-79A	CA ROUTE 198	36	11.44	120	48.09	PANCHO RICO FORM.TPR
269/73	GABBRO	73-M-79B	CA ROUTE 198	36	11.51	120	47.90	GRANIT.GR.GRD.GQD.GB
270/73	SANDSTONE	73-M-80A	CA ROUTE 198	36	11.76	120	47.90	PANCHO RICO FORM.TPS
271/73	SANDSTONE	73-M-80B	PEACHTREE ROAD	36	10.08	120	46.68	PANCHO RICO FORM.TPR
272/73	MUDSTONE	73-M-81A	PEACHTREE ROAD	36	10.08	120	46.68	PANCHO RICO FORM.TPR
273/73	MUDSTONE	73-M-81B	CA. ROUTE 25	36	12.65	120	51.88	PANCHO RICO FORM.TPR
274/73	SANDSTONE	73-M-82A	DUDLEY ROAD	36	0.35	120	55.57	UNNAMED UNIT-MAR.TUS
275/73	SILICEOUS SHALE	73-M-82B	GARRISSERE CANYON	36	0.85	120	57.10	MONTEREY FORM.TM
276/73	MUDSTONE	73-M-83A	GARRISSERE CANYON	36	0.85	120	57.10	MONT.FORM.PHOSPHATIC
277/73	SILTSTONE	73-M-83B	PARIS VALLEY ROAD	36	1.82	120	57.52	PANCHO RICO FM.PHOSP
278/73	MUDSTONE	73-M-84A	SAN ANTONIO BRIDG	35	59.05	121	14.23	MONTEREY FORM.TM
279/73	PORCELANITE	73-M-84B	SAN MIG.LOOP ROAD	35	58.65	121	14.97	MONTEREY FORM.TM
280/73	SANDSTONE	73-M-85A	SAN MIG.LOOP ROAD	35	58.22	121	16.10	UNNAMED MARINE FORM.
281/73	SANDSTONE	73-M-85B	SAN MIG.LOOP ROAD	35	55.87	121	14.68	UNNAMED MARINE FORM.
282/73	SANDSTONE	73-M-86A	SAN MIG.LOOP ROAD	35	55.87	121	14.68	UNNAMED MARINE FORM.
283/73	MUDSTONE	73-M-86B	DEL VENTURI ROAD	36	0.02	121	15.17	UNNAMED MARINE FORM.
284/73	MUDSTONE	73-M-87A	DEL VENTURI ROAD	36	1.46	121	17.17	MONTEREY FORM.TM
285/73	MUDSTONE	73-M-87B	DEL VENTURI ROAD	36	3.83	121	18.74	MONT.FORM.PHOSPHATIC
286/73	QTZ-BIOTITEROCK	73-M-88A	DEL VENTURI ROAD	36	4.24	121	19.30	GRANIT.GR.GRD.GQD.GB
287/73	SANDSTONE	73-M-88B	DEL VENTURI ROAD	36	6.23	121	25.95	VAQ.SANDSTONE TVQ
288/73	SANDSTONE	73-M-89A	DEL VENTURI ROAD	36	4.35	121	21.57	VAQ.SANDSTONE TVQ
289/73	SANDSTONE	73-M-89B	DEL VENTURI ROAD	36	5.10	121	24.10	VAQ.SANDSTONE TVQ
290/73	SHALE	73-M-90A	DEL VENTURI ROAD	36	6.23	121	26.95	CHURCH CR.FORM.TCC
291/73	SANDSTONE	73-M-90B	DEL VENTURI ROAD	36	6.23	121	26.95	CHURCH CR.FORM.TCC
292/73	QTZ-BIOTITEROCK	73-M-91A	RD TO SULFUR SPRG	36	4.27	121	18.85	META SEDIMENTARY MSC
293/73	SANDSTONE	73-M-91B	RD TO SULFUR SPRG	36	3.78	121	18.18	PANCHO RICO FORM.TPR
294/73	SANDSTONE	73-M-92A	RD TO SULFUR SPRG	36	4.40	121	17.13	VAQ.SANDSTONE TVQ
295/73	MUDSTONE	73-M-92B	RD TO SULFUR SPRG	36	4.77	121	16.32	MONT.FORM.PHOSPHATIC
296/73	MUDSTONE	73-M-93A	RD TO SULFUR SPRG	36	4.84	121	16.07	MONTEREY FORM.TM
297/73	MUDSTONE	73-M-93B	RD TO SULFUR SPRG	36	4.88	121	15.75	PANCHO RICO FORM.TPR
298/73	MUDSTONE	73-M-94A	VISTA POINT SNANT	35	47.48	120	53.60	MONTEREY FORM.TM
299/73	MUDSTONE	73-M-94B	BEE ROCK ROAD	35	47.35	120	56.27	MONTEREY FORM.TML
300/73	SANDSTONE	73-M-95A	BEE ROCK ROAD	35	47.22	120	56.73	VAQ.CALC.SANDST.TVC
301/73	SANDSTONE	73-M-95B	BEE ROCK ROAD	35	[illegible]	120	[illegible]	[illegible]

LAB. NO.	NAME OF MATERIAL	FIELD NO.	LOCATION	LATITUDE DEG.	MIN.	LONGITUDE DEG.	MIN.	FORMATION
303/73	SHALE	73-M-96B	BEE ROCK ROAD	30	47.30	120	56.42	MONTEREY FORM.TMC
304/73	SHALE	73-M-97A	BEE ROCK CANYONRD	35	46.65	120	54.04	MONTEREY FORM.TMC
305/73	MUDSTONE	73-M-97B	BEE ROCK CANYONRD	35	46.65	120	54.04	MONTEREY FORM.TM
306/73	GRANITE	73-M-98A	OAK FLAT ROAD	35	39.63	120	43.46	GRANIT.GR.GRD.GQD.GB
307/73	MUDSTONE	73-M-98B	PASO ROBLES ROAD	35	38.93	120	43.76	MONT.FORM.PHOSPHATIC
308/73	SANDSTONE	73-M-99A	PASO ROBLES ROAD	35	38.93	120	42.96	PASO ROBLES FORM.QTP
309/73	SHALE	73-M-99B	CAMBRIA ROAD RT46	35	34.05	120	44.76	MONT.FORM.PHOSPHATIC
310/73	MUDSTONE	73-M100A	VINEYARD ROAD	35	33.08	120	44.94	MONTEREY FORM.TML
311/73	PHOSPHORITE	73-M100B	E TOMASINI CANYON	36	30.94	121	46.24	MONT.FORM.PHOSPHATIC
312/73	PHOSPHORITE	73-M100C	E TOMASINI CANYON	36	30.94	121	46.24	MONT.FORM.PHOSPHATIC
313/73	PHOSPHORITE	73-M101A	E JUAN MATTE CANY	36	30.61	121	45.86	MONT.FORM.PHOSPHATIC
314/73	PHOSPHATIC PELL	73-M101B	TULARCITOS RD CUT	36	25.27	121	36.65	MONT.FORM.PHOSPHATIC
315/73	PHOSPHATIC PELL	73-M101C	TULARCITOS RD CUT	36	25.27	121	36.65	MONT.FORM.PHOSPHATIC
316/73	PHOSPHATIC PELL	73-M102A	JAMESBURG ROAD	36	15.50	121	25.43	MONT.FORM.PHOSPHATIC
317/73	PHOSPHATIC PELL	73-M102B	JAMESBURG ROAD	36	15.50	121	25.43	MONT.FORM.PHOSPHATIC
318/73	PHOSPHATIC PELL	73-M102C	JAMESBURGE ROAD	36	15.50	121	25.43	MONT.FORM.PHOSPHATIC
319/73	MUDSTONE	73-M103A	ARROYO SECO ROAD	36	16.84	121	19.43	MONT.FORM.PHOSPHATIC
320/73	MUDSTONE	73-M103B	ARROYO SECO ROAD	36	16.84	121	19.43	MONT.FORM.PHOSPHATIC
321/73	CLAY SEAM	73-M103C	RELIZ CANYON ROAD	36	13.88	121	16.90	MONT.FORM.PHOSPHATIC
322/73	CLAY SEAM	73-M104A	RELIZ CANYON ROAD	36	13.88	121	16.90	MONT.FORM.PHOSPHATIC
323/73	MUDSTONE	73-M104B	RELIZ CANYON ROAD	36	13.88	121	16.90	MONTEREY FORM.TM
324/73	PHOSPHA-PELLETS	73-M104C	RELIZ CANYON ROAD	36	11.67	121	16.65	MONT.FORM.PHOSPHATIC
325/73	PHOSPHA-PELLETS	73-M105A	RELIZ CANYON ROAD	36	11.67	121	16.65	MONT.FORM.PHOSPHATIC
326/73	SHALE	73-M105B	SULPHUR SPRING RD	36	2.46	121	13.39	MONT.FORM.PHOSPHATIC
327/73	SHALE	73-M105C	SULPHUR SPRING RD	36	2.46	121	13.39	MONT.FORM.PHOSPHATIC
328/73	MUDSTONE	73-M106A	SULPHUR SPRING RD	36	2.46	121	13.39	MONT.FORM.PHOSPHATIC
329/73	MUDSTONE	73-M106B	SULPHUR SPRING RD	36	2.46	121	13.39	MONT.FORM.PHOSPHATIC
330/73	MUDSTONE	73-M106C	FELIZ CANYON	36	3.66	121	4.54	MONT.FORM.PHOSPHATIC
331/73	MUDSTONE	73-M107A	FELIZ CANYON	36	3.66	121	4.54	MONT.FORM.PHOSPHATIC
332/73	MUDSTONE	73-M107B	FELIZ CANYON	36	4.37	121	4.63	MONTEREY FORM.TM
333/73	MUDSTONE	73-M107C	FELIZ CANYON	36	4.37	121	4.63	MONT.FORM.PHOSPHATIC
334/73	MUDSTONE	73-M108A	FELIZ CANYON	36	4.75	121	4.72	MONT.FORM.PHOSPHATIC
335/73	MUDSTONE	73-M108B	FELIZ CANYON	36	4.75	121	4.72	MONT.FORM.PHOSPHATIC
336/73	MUDSTONE	73-M108C	FELIZ CANYON	36	4.75	121	4.72	MONT.FORM.PHOSPHATIC
337/73	MUDSTONE	73-M109A	SAN LUCAS CANYON	36	0.13	121	3.97	MONT.FORM.PHOSPHATIC

LAB. NO.	NAME OF MATERIAL	FIELD NO.	LOCATION	LATITUDE DEG.	MIN.	LONGITUDE DEG.	MIN.	FORMATION
338/73	MUDSTONE	73-M109B	SAN LUCAS CANYON	36	0.13	121	3.97	MONT.FORM.PHOSPHATIC
339/73	SILTSTONE	73-M109C	PARIS VALLEY ROAD	36	1.82	120	57.52	PANCHO RICO FORM.TPI
340/73	SILTSTONE	73-M110A	PARIS VALLEY ROAD	36	1.82	120	57.52	PANCHO RICO FORM.TPI
341/73	SILTSTONE	73-M110B	PARIS VALLEY ROAD	36	1.82	120	57.52	PANCHO RICO FORM.TPI
342/73	SILTSTONE	73-M110C	PARIS VALLEY ROAD	36	1.82	120	57.52	PANCHO RICO FORM.TPI
343/73	MUDSTONE	73-M111A	DEL VENTRI ROAD	36	3.83	121	18.74	MONT.FORM.PHOSPHATIC
344/73	MUDSTONE	73-M111B	PINE CANYON ROAD	36	8.73	121	12.10	MONT.FORM.PHOSPHATIC
345/73	MUDSTONE	73-M111C	PINE CANYON ROAD	36	8.73	121	12.10	MONTEREY FORM.TM
346/73	MUDSTONE	73-M112A	JOLON ROAD	35	54.25	120	58.10	MONT.FORM.PHOSPHATIC
347/73	MUDSTONE	73-M112B	JOLON ROAD	35	54.25	120	58.10	MONT.FORM.PHOSPHATIC
348/73	MUDSTONE	73-M112C	W INDIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC
349/73	SANDSTONE	73-M113A	W INDIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC
350/73	SANDSTONE	73-M113B	W INDIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC
351/73	CLAY SEAM	73-M113C	W INDIAN CREEK	35	28.48	120	23.54	MONT.FORM.PHOSPHATIC

APPENDIX C

Computer Programs

ROGRAM NO. 1.
IST OF SAMPLE IDENTIFICATION INFORMATION

This program provides a table containing the lab number, ame of material, field number, location, county name, latitude, ngitude, and formation (or other reference) for each sample.

Card No.	*Type*
	Job card

	System control cards
	a) //STEPA EXEC FORTGCLG
	b) //FORT. SYSIN DD *

	"LIST OF SAMPLE IDENTIFICATION INFORMATION" FORTRAN IV source deck

	System control cards
	a) //Gϕ. FT06F001 DD SYSϕUT = A
	b) //Gϕ. FT05F001 DD *

	List of counties (12 cards)

Columns	*Format*	*Entry*	*Description*
1–80	5 (4A4)	A1(K)	Twelve cards each with 5 counties in alphabetical order 5A16 format (Ex: "Alameda," etc.)

Option card

Columns	*Format*	*Entry*	*Description*
1 –2	12	KFM	Number of personal reference cards to be read (Ex: "26" formations). If "O" none will be read.
3 –4	12	LIST	If LIST = O no more list follow, IF LIST ≠ O another list will follow this.

Personal reference cards (optional) If KFM ≠ O, KFM cards are included.

olumns	*Format Entry*	*Description*
1–20	5A4	First 20 columns of KFM cards contain name formation etc., to appear in table.

8. Sample Identification Cards
These are the sample I.D. cards used by the DMG Geochemical Section for each sample submitted for analysis.

Columns	*Format*	*Entry*	*Description*
1–7	A4,A3	X(1), X(2)	Lab number
8–22	3A4,A3	X(3)–(6)	Name of material
23–30	2A4	X(7), X(8)	Field number
31–47	4A4, A1	X(9)–X(13)	Location (nearest geographical feature)
54–55	12	LAT	Degrees of latitude
56–59	F4.2	FLAT	Minutes of latitude to nearest one–hundreth
60–61	12	L	Degrees of longitude with the 100 understood (i.e. "121" degrees is represented by "21").
62–65	F4.2	FLϕN	Minutes of longitude to nearest one–hundredth
69–70	12	ICO	County number (see alphabetical list of 58 counties) 59 = "OUT OF STATE" = blank
79–80	12	IFM	Personal reference number (Ex: number of formation from list of formations to be read in)

9. End Card

9's in all columns

10. Repeat cards 6 – 9 if LIST ≠ O

11. System control card

/*

*STORAGE AND RETRIEVAL OF CHEMICAL ANALYSES**

The format for entering chemical data on computer cards is the periodic table. Data for the first ten elements can be entered on the first card. The format for entering these ten elements is: (10 (A1, F6.2), 2A4, 1X, I1). Hydrogen (atomic no. 1) would be entered in columns 2 to 7. Helium (Z=2) would be entered in columns 9 to 14. Oxygen would be entered in columns 51–56. These are the 6 columns prior to and including column 56 (atomic no. 8 times 7 columns per element). Columns 1, 8, and 50 can be used to indicate whether the data is in ppm ( ), ppb (*), or percent (%). Since oxygen is included as one of the elements, all other data is reported in the elemental form. Lab numbers are right adjusted in columns 72–78.

Cards for the remaining elements in the periodic table are prepared in the same way. Column 80 is used to indicate the decade of the atomic number. For example, data for cadmium (Z = 48), would be in columns 51–56 of a card with the number 4 in column 80. Data for tin (Z = 50) would be in row 10 of the same card since Z = 50 (4 x 10 + 10).

Only numbers and decimal points can be used in the data columns. The only exceptions are columns 1, 8, 15, 22, 29, 36, 43, 50, 57, and 64 used to indicate data in other than ppm concentrations.

The advantages of this method of data entry are:

1. Subsequent analyses of additional elements can be added to the data set without repunching the old data.
2. The systematic order of the elements remains unchanged with the addition of new analyses.
3. New users of the system could probably locate data for the elements simply by knowing that it was "based upon the periodic table."

A disadvantage of the system is the large number of cards needed to represent an analysis. All ten cards representing the periodic table need not be included unless the analysis happens to have elements from each decade of the periodic table.

---

*This format is only used to punch the computer cards.

PROGRAM NO. 2.
TABLE OF CHEMICAL ANALYSES

This program provides a table containing chemical analyses. The cards for the input are prepared as explained above in "Storage and retrieval of chemical analyses."

Card No.	*Type*
1.	Job card

2.	System control cards
	1) //STEPA EXEC FORTGCLG
	b) //FORT. SYSIN DD*

3.	"TABLE OF CHEMICAL ANALYSES" FORTRAN IV source deck

4. System control cards
a) //STEPA EXEC FORTGCLG
b) //FORT. SYSIN DD*

5. Data card A (column 80 =1)

Column	*Format*	*Entry*	*Description*
30–35	F6.2	Phosphorus (%)	

6. Data card B (column 80 =2)

58–63	F6.2	CU	Copper (ppm)
65–70	F6.2	Zn	Zinc (ppm)

7. Data card E (column 80 = 3)

16–21	F6.2	As	Arsenic (ppm)

8. Data card D 1 (column 80 = 4)

51–56	F6.2	CD	Cadmium (ppn

9. Data card E (column 80 (= 7)

65–70	F6.2	HG	Mercury (ppb)

10. Data card F (column 80 = 8)

9–14	F6.2	PB	Lead (ppm)
72–78	2A4	AN ϕ,Z	Lab number

Repeat cards 5 through 10 for each sample.

11. End card

9's in all columns

Repeat card 11 five more times. (The number of end ca is equal to the number of data cards representing a sin sample, 6 in this case.)

12. System control card

/*

This program can be adapted to other elements as the ne arises.

PROGRAM NO. 3.
STEPWISE REGRESSION ANALYSES

This program computes a multiple linear regression equat in a stepwise manner, giving correlation matrix and plotting correlation curves for various elements. This program was w ten by the Health Sciences Computing Facility of Universit California, Los Angeles; refer to its program # BMDP2R details.

APPENDIX D

Digestion Procedures

TAL DIGESTION TECHNIQUE LOSED DIGESTION SYSTEM)

rdinary digestion techniques could not be employed on sam- s to be tested for mercury and other volatile elements, because he danger of losing them due to their volatility. Therefore, w heating of the digest in a closed system was required during iple preparation. Wet digestion of the samples was achieved h a 1:1 mixture of concentrated nitric and sulfuric acids, with apparatus (Figure 30) in a reflux position.

paratus

he apparatus mainly used for digesting samples for mercury lysis consisted of a digestion flask, a modified soxhlet extrac- a dropping funnel, and a Friedrichs condenser.

he digestion apparatus (Figure 30) is a modified version of t used by the Association of Official Analytical Chemists orwitz, 1970) to digest fruit pulps and other vegetables for rcury determinations. All units of apparatus are made from ex glass. Unit 3 is a modified soxhlet extractor, 5 centimeters utside diameter, with a 250 millimeter capacity, a facility to rflow, and without an inner siphon tube but equipped with opcock on the tube leading to the digestion flask, unit 1. With stopcock open, the apparatus is in the reflux position, when ed, this unit serves as the trap for condensed steam and acid es. The top of the unit is attached to a 34–cm–long Frie- hs condenser, unit 4. The bottom of unit 3 is attached ugh the center neck of a two–neck, round bottom, 500 ml stion flask, unit 1. The two necks of this flask are 3 cm apart rovide working clearance. The offset neck is used to attach -ml dropping funnel, unit 2.

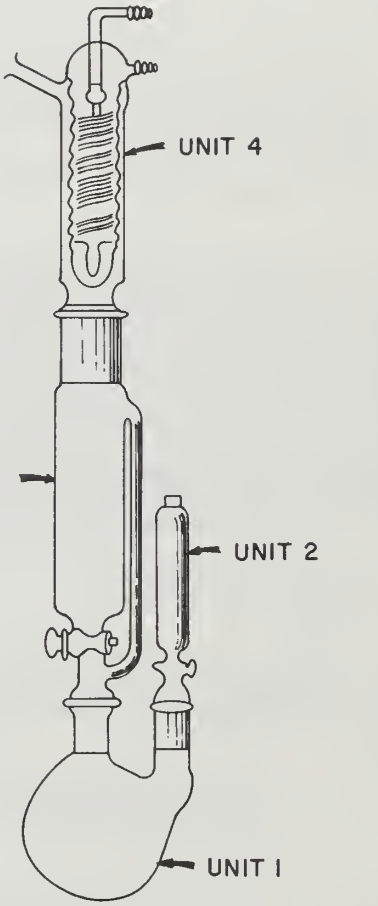
ecause mercury compounds tend to absorb the glassware aces, this apparatus and the separators were rinsed with a te HNO_3 and then with deionized distilled water. Also, dur- he course of digestion of a series of samples, blanks were run checked for possible contamination at least twice a week. usual workload was eight samples a day.

egents

- Concentrated HNO_3 (Baker Special, suitable for mercury determination);
- HNO_3 – H_2SO_4 mixture (1:1); and
- Urea – 40 percent (W/V)

cedure

Thoroughly mix the pulverized sample on a plastic sheet and spread it flat. Weigh 10 gm of the sample by taking increments from all sides, corners and grids in order to get a representative sample from the pulverized bulk powder. Drop this powder in the digestion flask and dampen it with a few ml of (1:20) HNO_3. Let it stand overnight; or



UNIT I. DIGESTION FLASK
UNIT 2. DROPPING FUNNEL
UNIT 3. MODIFIED SOXHLET EXTRACTOR
UNIT 4. FRIEDRICH CONDENSER

Figure 30. Digestion apparatus for volatile elements.

2. Heat gently on a heating mantle by setting rheostat at 30 volts for 20 to 30 minutes. The stopcock should be kept in a reflux position while heating.
3. Add, dropwise, 30 ml HNO_3 – H_2SO_4 (1:1) mixture. Change the rheostat to 60 volts. Heat until dense white H_2SO_4 fumes cease with stopcock in the reflux position.

Note: Because nitrous oxide fumes rise into the reflux condenser, it is necessary to rinse the apparatus from the top with a minimum amount of deionized distilled water. While rinsing, care should always be taken not to increase the volume significantly.

4. Boil for one hour. Count the time after the first bubble starts.

5. After boiling for one hour, add 10 ml concentrated HNO_3. Heat for 15 minutes more.

6. Rinse the apparatus with water.

7. Add 10 ml of 40 percent urea. Close the stopcock. Heat and collect the solution in the soxhlet extractor, Figure 30, unit 3, for 15 to 20 minutes.

8. Shut down, cool and pour all the contents of the flask, including the fine suspended particles, into a 250–ml volumetric flask. Cool, make to volume with distilled water and transfer to a polyethylene bottle.

9. Prepare blank solutions in the same way and check for possible contamination.

Important Note: Do Not Filter. When taking an aliquot for mercury determination, agitate the bottle and include the suspended particles in the aliquot. If filtered, the mercury determined is always less than the amount present in the sample. For the determination of other elements, filter and then take the aliquot. For arsenic determination, it is necessary to use a special treatment to remove the nitric acid present in the digest because it hinders the arsenic determination. Nitric acid was completely removed from sample digests by slowly heating with concentrated sulfuric acid until brown fumes of nitrous oxide were no longer visible and white, dense fumes of sulfuric acid evolved.

TOTAL DIGESTION TECHNIQUE (OPEN DIGESTION SYSTEM)

Because of the contamination problem, discussed earlier in the test, various digestion technqiues were developed and tested to digest the bedrock samples. The following is the account of these techniques:

Method A – Mechanically agitate 10 gm of sample for one hour with 20 ml of 2N HNO_3. After agitation, decant the solution for analysis.

Method B – Heat 5 gm of sample for two hours with 40 ml of 2N HNO_3; cool and dilute to 100 ml volume with deionized water.

Method C – This is the total digestion technique used in digestion of stream sediments. Heat 10 gm of sample in a special closed digestion apparatus with a mixture of 40 ml HNO_3 and H_2SO_4 (1:) and 10 ml of 40 percent urea; cool and dilute to 250 ml volume with deionized water.

Method D – This may be called an open version of the t al digestion technique described in C. Heat 10 g of sample with a mixture of 40 ml HNO_3 and H_2 O_4 (1:) and 10 ml of 40 percent urea in sand bat on a hot plate.

Method E – This technique is used mainly in rapid sili te analysis and is known as the B solution me d (Riley, 1958). Heat 0.5 gm of sample in te n crucibles on water bath, with 10 ml perchloric d 15 ml hydrofluoric acids; cool and dilute the c ır digest to 500 ml with deionized water.

Table 8 shows the results of analyses of 15 samples digeste by using all the above techniques. It is clear that methods B a E bring out most of the cadmium in solution. Method E requ es a long digestion time and is not desirable for samples having w cadmium contents as there is a dilution factor of 1000 invol d. Therefore, the remaining samples were digested by method I or cadmium determination.

An attempt was made to use hydrochloric acid instea of nitric acid in methods A and B. However, this produced very e white precipitates which interfered with the analysis by ato ic absorption spectrophotometer, so nitric acid was used thro out.

Past experience with marine and stream sediments showe e necessity of using the closed digestion technique for mercury d other volatile elements. As the phosphatic samples seeme o raise a special problem, it was decided to compare the resul of digests obtained by methods C (closed digestion) and D (c n digestion) for arsenic, copper, lead, mercury, and zinc. No preciable differences were found in the resulting analyses.

All the samples were digested by method D for all anal s except cadmium. This was contrary to prior experience d probably can be explained by the lack of methyl mercury in e bedrock samples, thus allowing the use of an open diges n system.

ACID EXTRACTION TECHNIQUE

The detection limit in samples digested by the total diges technique was too low to measure cadmium in the low con trations in which it occurs in some of the stream sediment s ples. Therefore, an acid extraction method was utililzed which 20 g of the pulverized sample in a bottle with 40 ml of (two molar) HCI was shaken for one hour on a mechan shaker. After one hour, the suspension was filtered and used cadmium determination.

Table 8. Comparison of various digestion techniques.

SAMPLE #	*METHOD A*	*METHOD B*	*METHOD C*	*METHOD D*	*METHOD E*	*Values considered for report are calculations.*
101/73	36.5$^{(2)}$	89.5 $^{(2)}$	28.0	59.5	90.0	90.0
111/73	19.5$^{(2)}$	22.6	15.0	18.8	20.0	22.6
112/73	15.0$^{(2)}$	19.4	14.0	16.3	20.0	20.0
115/73	75.5$^{(2)}$	96.0	64.6$^{(2)}$	66.3	70.0	96.0
116/73	41.5$^{(2)}$	47.2	39.0	41.0	50.0	50.0
121/73	19.8$^{(3)}$	38.5 $^{(2)}$	16.0	17.5	30.0	38.5
155/73	32.0$^{(2)}$	32.8	20.0	27.3	30.0	32.8
159/73	72.5$^{(2)}$	166.0	21.0	43.8	150.0	166.0
160/73	57.5$^{(2)}$	121.0 $^{(2)}$	22.0	35.5	120.0	121.0
162/73	22.0$^{(2)}$	27.6	24.5$^{(3)}$	23.0	27.0	27.6
167/73	225.0$^{(2)}$	348.0	68.0	92.5	300.0	348.0
168/73	175.0$^{(2)}$	348.0	53.0	75.0	330.0	348.0
171/73	46.5$^{(2)}$	52.0	42.7$^{(2)}$	32.3	50.0	52.0
206/73	29.5$^{(2)}$	32.2	23.2	26.3	20.0	32.2
277/73	43.4$^{(2)}$	99.0	25	48.5	100.0	100.0

Note: The figure in parentheses is the number of times the sample was digested, and the value given is the average of this number.

APPENDIX E

Analytical Techniques

MERCURY

Apparatus

1. Atomic Absorption Spectrophotometer: Perkin Elmer, Model 403, equipped with concentration read out, deuterium background corrector, mercury hollow cathode lamp and a chart recorder, model 165.

2. Laboratory kit for flameless mercury determination: Refer to Figure 31. This device was assembled in the Division laboratory as follows:

   a) Needle valve: Lab–Crest threaded, glass needle valve, with angle design;

   b) Flowmeter: Monostat air–flowmeter;

   c) Reaction vessel: prepared by cutting a 1000 ml plain hydrometer pyrex cylinder in half;

   d) Absorption cell: made up of clear, transparent, plastic tube, 2.5 cm o.d. and 10 cm length, with quartz end windows.

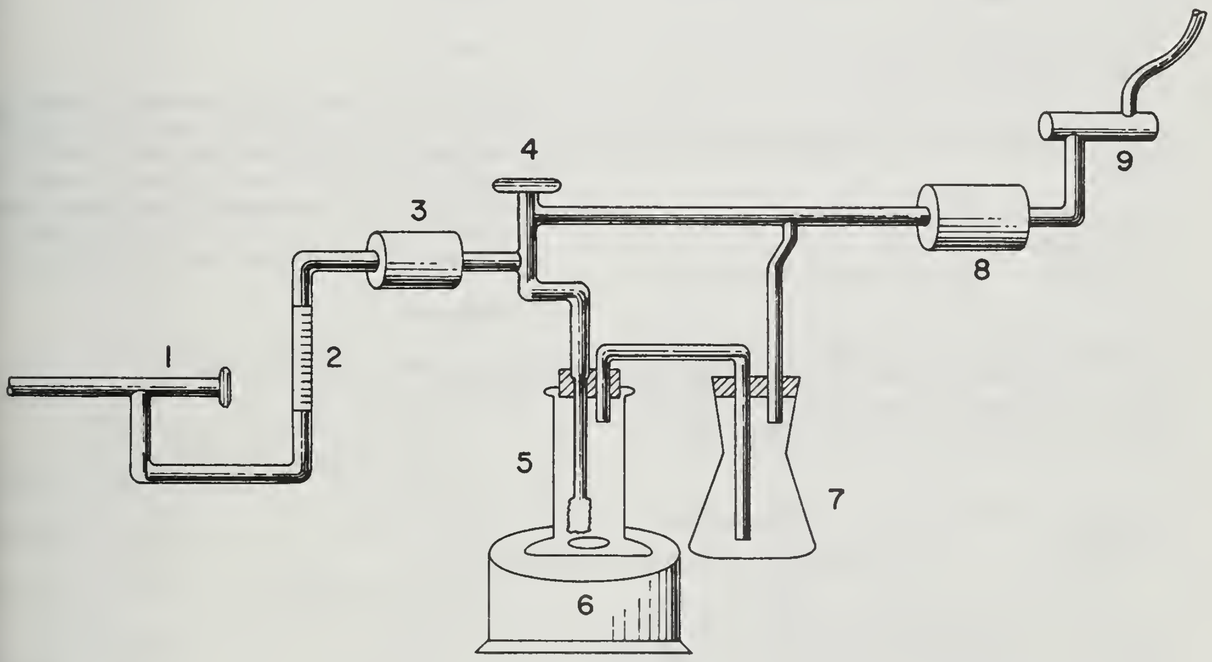
Additionally there are moisture traps, a dehydration trap, and a trap to remove mercury from the incoming air, if any is present. The whole system is an open system.

Reagents

1. Stannous Choride solution: 10 percent weight/volume prepared in 20 percent HCL. Prepared fresh every 2 to 3 months.

2. Anhydrone (magnesium perchlorate): commercially available.

3. Mercury standards: stock solution of 1000 ppm Hg, purchased from Harleco, was used to prepare the working standards. Serially dilute to 0.1, 0.5, 1, 5, 10,



1. NEEDLE VALVE
2. AIR-FLOWMETER
3. ACTIVATED CHARCOAL TRAP
4. TWO-WAY STOPCOCK
5. REACTION VESSEL
6. MAGNETIC STIRRER
7. MOISTURE TRAP
8. DEHYDRATION COLUMN
9. ABSORPTION CELL WITH QUARTZ WINDOWS

Figure 31. Non-flame mercury device.

and 25 ppb Hg, using 10 percent HCl. Because of the acid diluting medium for the standards, the mercury values remained reasonably uniform and were used for a period of one week before fresh working standards had to be prepared. The standard blank was prepared in the same way, and each blank was tested for any possible contamination. One of the standards was run as an unknown between each batch of samples to check reproducibility.

4. Activated charcoal and glass wool.

Procedure for Flameless Mercury Measurement

1. Set up the atomic absorption (AA) unit with the Hg hollow cathode lamp and with flow–through absorption cell in place of burner, keeping the following settings:

   Wavelength – 253.7 Å
   Slit setting – 5 (3 mm, 20 Å
   Lamp current – 10 milliamps (mA)
   Air flow rate – 835 ml/min at 1 atmosphere and 70° F. This can be adjusted by keeping the stainless steel ball in the air–flowmeter at 8.
   Concentration mode – 1–80 (approx.)

   Adjust wavelength for maximum energy; align absorption cell for minimum absorbance.

2. Turn on the deuterium background corrector and let it warm for 10 to 15 minutes.

3. Turn on the chart recorder keeping the following settings:

   Input switches – float and negative
   Chart speed – 5 mm/min
   Power Knob – "Amp" for warm–up and then to "Servo."

4. Keep the clean reaction vessel with a two–way stopcock in the by–pass position. Keep the magnetic stirrer in an off position, and adjust the air flow at the rate of 835 ml/min. Zero the instrument with the blank mercury–free air.

5. Change the activated charcoal, anhydrone and glass wool daily.

6. Take 100 ml deionized H_2O in a reaction vessel and pipet 10 ml of the standard or agitated and unfiltered sample solution. If standards are used, start with the lowest concentration. The standards which were used for the present analysis contained 1, 5, 10, and 25 ppb Hg, respectively.

7. Turn the knob of the chart–recorder from "Servo" to "Chart." Before starting the actual analysis, adjust 0 and 100 percent concentration using the ZERO and GAIN controls of the recorder. Use blank (100 ml H_2O + 2 ml 10 percent $SnCl_2$) for adjusting 0 percent and 25 ppb Hg standard for adjusting 100 percent.

8. Add 2 ml of 10 percent $SnCl_2$, using a 2 ml tip–u pipette. Close the reaction vessel immediately.

9. Start the magnetic stirrer and activate aeration b turning on the two–way stopcock. Numerical rea out of the instrument and the readout on the r corder will be recorded simultaneously. Write th identifying sample or standard number on chart p per.

10. When the intensity in ppb reaches zero on the rea out of the instrument, turn off the magnetic stirr switch aeration to bypass position, and remove t stopper from the reaction flask. At the same tin change recorder from "Chart" to "Servo."

11. Rinse down the fritted aeration tube with HN (1:20) and then with distilled water. About once week, or more often if necessary, this fritted aerati tube is cleaned in an ultrasonic bath, because t digest contains suspended particles that fill the po in the fritted portion of the aeration tube.

Figure 32 represents the working curve drawn from the pea obtained on AA recorder by running various standards. T curve was used for all samples to convert observed peak heig into corresponding concentrations.

(b) ARSENIC

Apparatus

All arsenic determinations were carried out on a Perki Elmer 403 atomic absorption spectrophotomet equipped with a three–slot burner head, model 165 cha recorder, and a deuterium background corrector. The used for arsine generation (Figure 33) is a laborat assembled device consisting of a reaction flask, dos column, collection balloon, and a four–way stopcock

Reagents

1. Concentrated hydrochloric acid.

2. Potassium iodide solution (15 percent)

3. Stannous chloride solution – 20 percent in 8N H

4. Zinc – granular, 20 mesh, analytical reagent gra

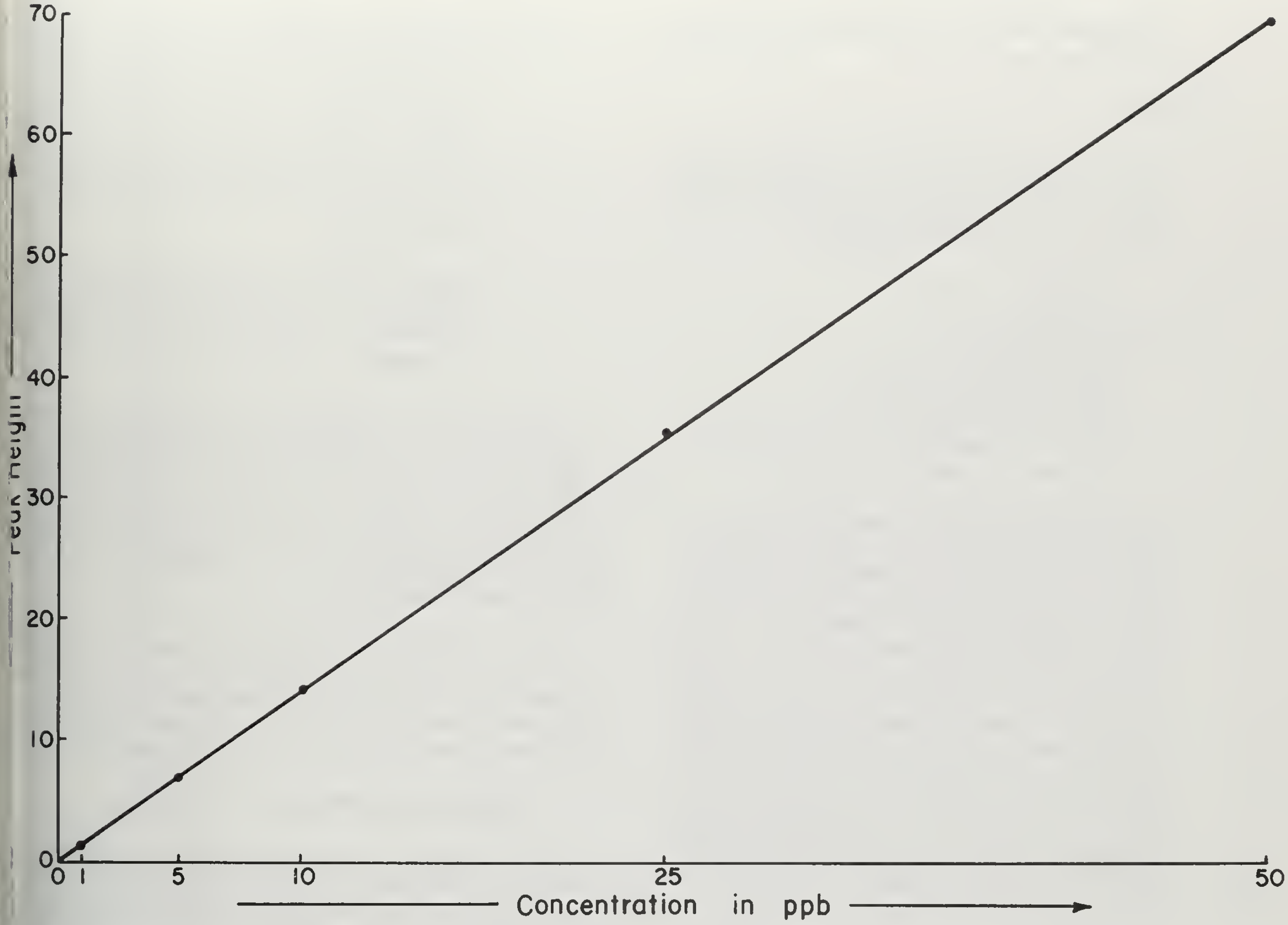
5. Arsenic standard – stock solution of 1000 ppm was prepared as follows:

   a) Weigh exactly 1.320 gm As_2O_3 (A.R. grade) dissolve in 25 ml of 20 percent potassium droxide.

   b) When the powder is dissolved completely, tralize this solution to a phenolphthalein point with 20 percent H_2SO_4.

   c) Dilute to one liter with 1 percent H_2SO_4.

   From this stock solution, working standards of 5, 25, 35, and 50 ppb As were prepared fresh d



ure 32. Working curve for mercury.

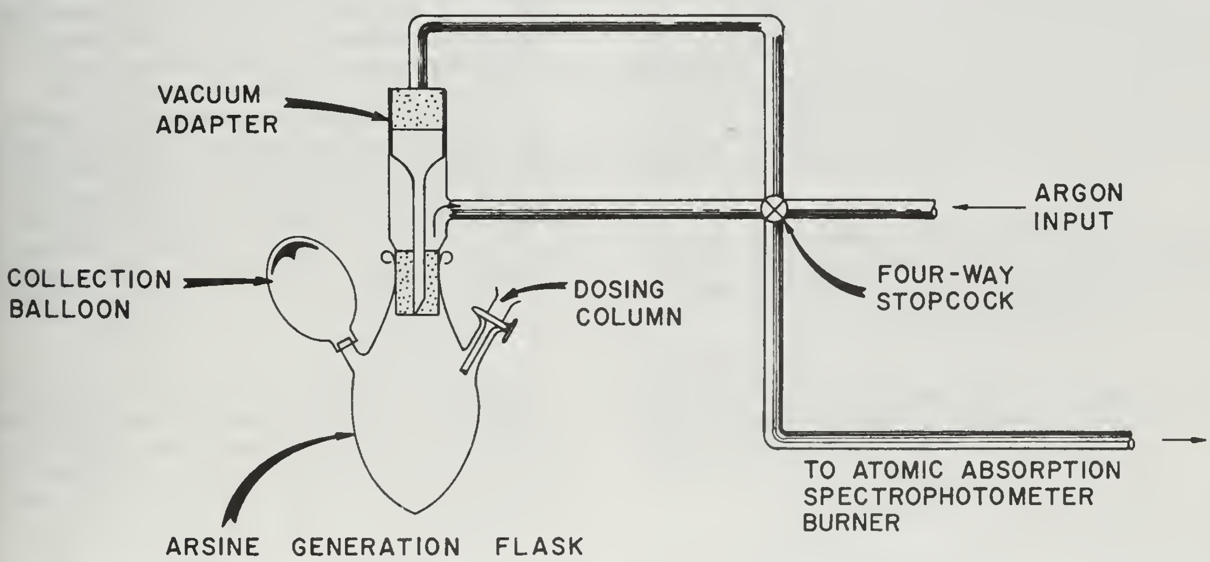


Figure 33. Arsine generation apparatus.

Other reagent solutions were prepared fresh for each batch of samples.

Procedure

1. Set up the A.A. unit with the As hollow cathode lamp; start the deuterium background corrector and a chart recorder and let them warm for 15 to 20 minutes. Keep the following settings:

    Wavelength – 193.7 Å
    Slit setting – 4
    Lamp current – 20 mA
    Fuel (H_2) Flow – 20
    Oxidant (Ar) Flow – 30
    Concentration Mode – 0–10
    Recorder Response – 2 or 3
    Recorder Chart Speed – 20 mm/min.

2. Make the required connections for hydrogen as the other fuel and argon as the other oxidant in the burner control chamber. Connect the auxilliary argon (from the back of the burner control) to the four–way stopcock (refer to Figure 33) and connect the other side of the four–way stopcock from where the arsine and hydrogen gas is driven off to the auxilliary oxidant position in the burner–nebulizer assembly. The other two sides of the four–way stopcock are connected to the generation flask for introducing the carrier argon gas and to carry the arsine and hydrogen produced to the burner nebulizer assembly. This can be done by changing the stopcock to the purge position. Argon in the bypass position is used to zero the instrument. Push the zero button when the flame is on.

3. Pipette 20 ml of standard or sample digest in the generation flask. If the sample has a higher concentration of arsenic, take less aliquot.

4. Add hydrochloric acid in such a quantity that the solution becomes 4 normal (N) when diluted to 40 ml with distilled water.

5. Add 1 ml of 15 percent potassium iodide solution with a tip–up pipette or micro–pipette. Mix well.

6. Add 1 ml of 20 percent stannous chloride solution, mix well and allow the solution to stand 3 to 4 minutes.

7. Completely wipe off the inside of the generation flask where additions are made. Connect the generation flask to the assembly with four–way stopcock in a bypass position.

8. Add 1.5 g of zinc metal to the generation flask through the side–dosing column and *immediately close the dosing funnel stopcock.* Wait 4 to 5 minutes until reaction between zinc and hydrochloric acid is complete and all the arsenic present in the solution has turned to arsine gas.

9. After 4 to 5 minutes, activate the recorder chart, light the flame and, keeping argon in bypass position, zero the instrument.

10. When zero is recorded on the chart, change four–way stopcock 90° to purge position, allow the auxiliary argon to flow through the flask a carry the collected arsine into the burner. Rec the peak, and when the recorder–pen comes to z position, return the four–way stopcock to byp position and turn off the flame. By turning off flame at this stage, considerable argon and hydro gas can be saved.

    Standard and sediment–digest blanks were run s eral times, and the average value obtained was s tracted from the corresponding values of standa s and samples.

The only danger in using this devise is that, due to moist , zinc particles stick to the surface of the stopcock of the reac vessel or dosing column. This might permit leakage of arsine s, which might be inhaled by an operator. To avoid this, dry e neck of the dosing column and generation flask completel y wiping with a Kimwipe. As a further precaution, a port e fume–hood was built over this device and connected to the la boratory exhaust hood system.

Figure 34 represents the working curve drawn from the p ks obtained by running various standards. This curve was use o calculate the concentration of all samples. Various stand ls were run between the analyses to check the reproducibi y, which was found to be very good (see Appendix H).

(c) CADMIUM, COPPER, LEAD, AND ZINC

Cadmium, copper, lead, and zinc were determined by d ct aspiration of respective standards and setting the working cu es on the AA instrument. The filtered digests of the samples re then aspirated, and concentrations were read directly on he digital readout screen. The deuterium background correcto as used for the analyses of cadmium, lead and zinc.

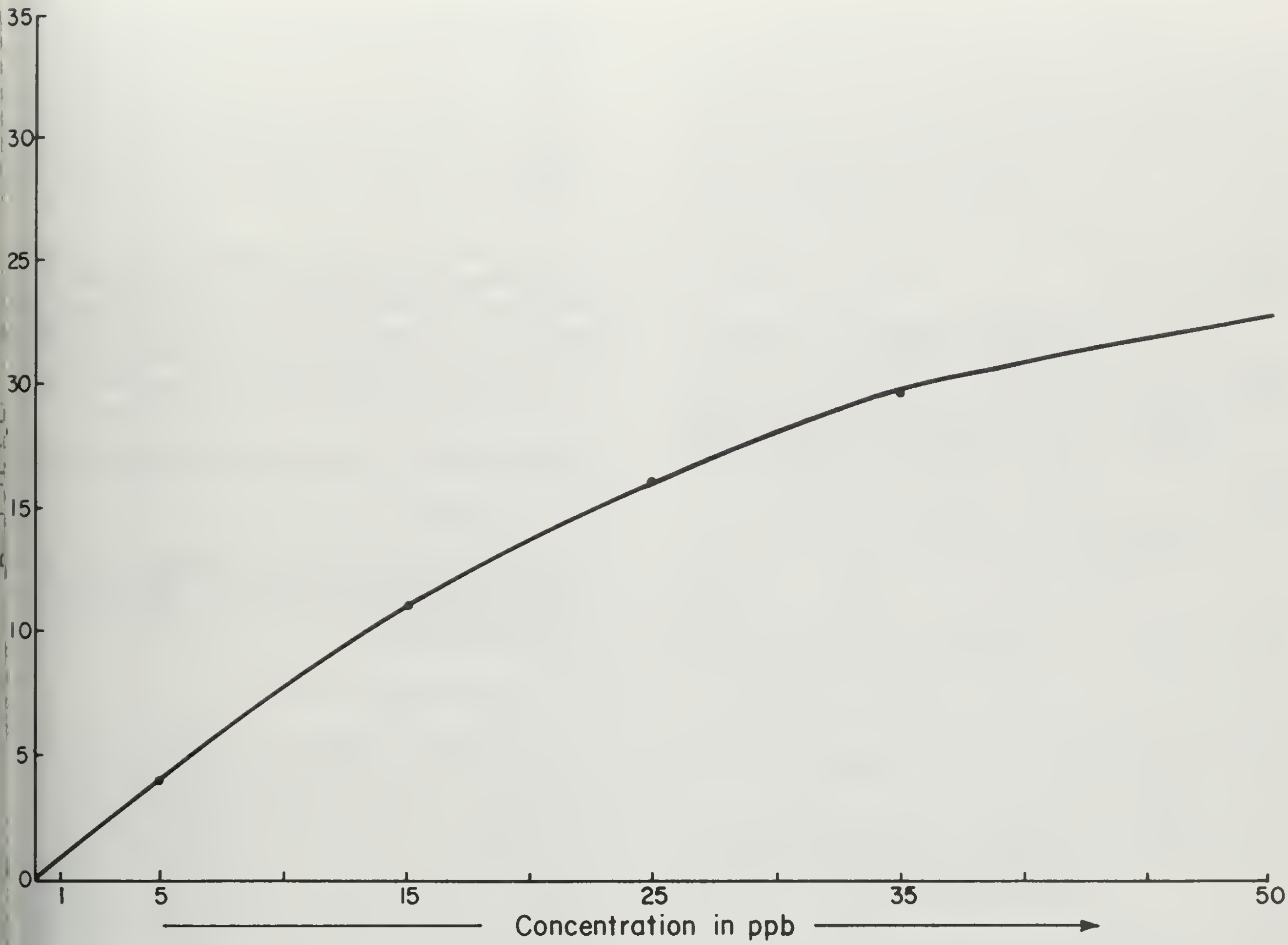
Because the total digestion technique was not sufficiently n-sitive to analyze the low quantities of cadmium present in se sediments, the acid extraction technique was used. The v es from each of the digestion methods were quite comparabl indicating that practically all of the cadmium had gone into lution with the acid extraction technique.

The acid extractions of most of the stream sediment sa les were analyzed for copper, lead, and zinc. The values obt ed were compared with those obtained from the totally dig ed samples, and it was found that the samples digested by the ci extraction technique showed lower concentrations than sa les digested by the total digestion technique; therefore, the ta digestion technique was used for copper, lead, and zinc.

(d) PHOSPHORUS

Phosphorus was determined with the x–ray spectromet by using one gram of 230–mesh sample, mixing it with one gra o Whatman CF–11 celluose powder, making pellets in Spex ps and analysing with an EDDT crystal and Cr target x–ray be All the phosphorus results are corrected for the presence of gh calcium.

The procedure for phosphorus determination is a mo ie technique after Fabbi (1971). The clayey nature of the ck



F re 34. Working curve for arsenic.

a lyzed precluded extensive pulverizing sieving to 400 mesh as gested by Fabbi.

1. Grind the sample for two minutes in Model #3800 Pitchford Pica Blender Mill, using stainless steel cylinders, stainless steel end buttons, two 15–mm stainless steel balls, and two aluminum end caps with four rubber '0' rings. Fill each vial approximately ⅓ full (~10 gm of less than #10–sieve material).
2. Split about ¼ of this sample for hand grinding to 230 mesh with agate mortar and pestle.
3. Dry the sample in the oven at 110° C.
4. Mix 1.0 gm of sample with 1.0 gm of Whatman CF–11 cellulose powder in a capped vial in a pica mill.
5. Prepare pellets, in duplicate, by filling Spex caps about half full of poly vinyl alcohol and other half with mixture of sample and cellulose, using a pressure of 16 tons per square inch.

The samples were then analyzed with a Cr Target x–ray tube, EDDT analyzing crystal, and a flow proportional counter at 1620 volts used in conjunction with a Phillips–Norelco vacuum spectrometer. X–radiation was generated at kV and 37.5 mA on the target tube. A baseline setting of 8.5 volts and a window–setting of 9 volts was used to discriminate against most of the CaK interference. The remainder of this interference was subtracted in the following estimation:

1. Each sample was analyzed four times for at least 20 seconds and up to 100 seconds (for very low P samples) for counts between 8.5 volts and 17.5 volts. This would include all P and about 3 percent of the Ca counts due to a sample.
2. Each sample was analyzed four times for 10 to 20 seconds for counts beyond 8.5 volts. This includes essentially all P and all Ca counts.
3. About 3 percent of the Ca counts occur in the interval between 8.5 and 17.5 volts. This was determined from average data on a sample of powdered $CaCO_3$ and Cf–11 (1:1) run at the beginning and end of each day. The correction factor (RCa) was

calculated using the following formula:

$$R_{Ca} = \frac{\int_{8.5}^{17.5} CR}{\int_{8.5}^{0.0} CR - \int_{8.5}^{17.5} CR}$$

Where:

$\int_{8.5}^{17.5} CR$ = counts per second between 8.5 and 17.5 volts for $CaCO_3$

$\int_{8.5}^{0.0} CR$ = counts per second greater than 8.5 volts for $CaCO_3$

4. The following was used to obtain Ca– corrected values for P:

$$CR_P = \int_{8.5}^{17.5} CR - \left[R_{Ca}\left(\int_{8.5}^{0.0} CR - \int_{8.5}^{17.5} CR\right)\right]$$

Where:

CR_P = corrected count rate for phosphorus

$\int_{8.5}^{17.5} CR$ = counts per second between 8.5 and 17.5 volts for the unknown or standard rock sample (PHA on "diff")

R_{Ca} = correction factor for Ca (see above)

$\int_{8.5}^{0.0} CR$ = counts per second beyond 8.5 volts for the unknown or standard rock sample (PHA on "integral")

5. A standard high–phosphate sample was counted before and after each set of unknown samples. A fixed position (no. 2) was used to eliminate orientation variability between runs. Standard rocks were run in the second fixed position (no. 4). Instrumental drift was eliminated from the data by using the ratio method. Count rates of unknown samples were first corrected for Ca interference, then divided by the corrected count rate for the high–phosphate standard. This standard was corrected in two ways: (a) the regular Ca interference was subtracted, and (b) interpolations of data at the beginning and end of each run were used as divisors to get ratio comparisons. (For example, if the Ca–corrected count rate for the standard was 2800 cps at the beginning of a run, and 2600 cps at the end, the count rates for the three unknowns would be divided by 2750, 2700, and 2650 cps, respectively.)

PREPARATION OF THE HIGH PHOSPHATE STANDARD

The high–phosphate standard was prepared by mixing Florida phosphate (National Bureau of Standards Sample 120a) and Cf – 11 cellulose powder and comparisons were made. During approximately two weeks of continuous use, this standard ga about 40 percent in x–ray intensity. Apparently, the cellulo partially destroyed by the x–ray beam. Similar change also observed on another specimen which increased the inter about 15 percent in 3 days. The cellulose destruction prob depends on the number of hours of exposure; the chang intensity is not gradual, so a correction for this change could be made.

A new standard ("A) was prepared by mixing 1.0 gr Florida Phosphate (National Bureau of Standards Sample 1 with 1.0 gm of a clayey sediment (11/73). The clayey mat acted as an excellent binder, and no destruction or chan intensity was observed in 4 weeks of continuous usage. A d cate sample ("B), which had received very little x–radia gave identical results before and after this period.

PREPARATION OF THE STANDARD WORKING CUR

A. Standards with 0 to 0.5% P_2O_5

Standard rocks G-2, GSP-1, AGV-1, BCR-1, SY-1, T-1, mixed with CF-11 cellulose powder (1:1). These were comp to the high-phosphate standard "A" to obtain a curve in range 0 to 0.5% P_2O_5.

B. Standards with 5 to 35 % P_{25}

Florida phosphate (National Bureau of Steandards 120a mixed with reagent grade $CACO_3$ in various proportions. gram of each of these was then mixed with CF–11 cell powder (1:1) to prepare a pellet. The standards were la P–10 (50% 120a + 50% CF–11), P–8 (40% 120a + $CaCO_3$ + 50% CF–11), P–6, (30% 120a + 20% CaC 50% CF–11), P–4 (20% 120a + 30% $CaCO_3$ + 50% CF P–2 (10% 120a + 40% $CaCO_3$ + 50% CF–11), and (50% $CaCO_3$ + 50% CF–11). These were then compared high–phosphate standard "A", as were all other samples.

Samples with unknown P_2O_5 concentrations were then pared to these two curves. For unknown samples with values between 0.5 and 5%, a curve was prepared by inter tion of data from the two standard curves.

CALCULATOR PROGRAMS FOR XRF ANALYSIS

The Commodore programming calculator was used to late the data. It takes about 2 hours to calculate data gene in 6 hours of x–ray operation. The five programs are as fo

1. Calculate the average count rate.

Enter counting time, CR_1, CR_2, CR_1, CR_4; record answer in Avg." Column of XRF data sheet. Program Code:

```
MMMM,N, 0.4, IV, 2 ¼, W, AC, 42. 6. 26. 26. 26. +
7393. 437., R, AC, 20, 1, 2, 3, 4                Ans.
```

2. Calculate R_{Ca} from "diff" and "integral" data fo ple P–O run at beginning and end of the day's

Enter $\int_{8.5}^{17.5,} CR$ $\int_{8.5}^{0.0,} CR$ record R_{Ca} and average the two values. Program Code:

5¼, W, AC, 42. 6. 23. 4363. 493. 63 + 7., R, AC, 50, 2000, Ans.: 0.02564

3. *Calcium correction.*

Store R_{Ca}, enter $\int_{8.5}^{17.5}$ CR $\int_{8.5}^{0.0}$ CR, and record "corrected cps"

Program Code:

R_a, IV, 2 ⅘, W, AC, . 6. 23. 4383. 72362. + 3.423. 637., 300, 5000, Ans.: 2936

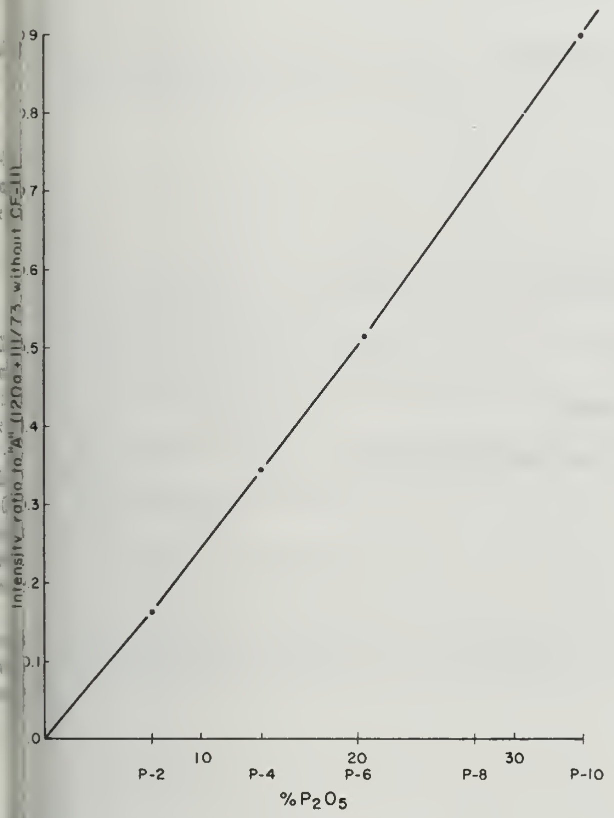


Figure 35. Working curve for P_2O_5 (high phosphate).

4. *Drift correction.*

Enter "corrected cps" for first or last analysis of an individual run, whichever is highest. Record first value under "cps drift" for first unknown if the first "B" corrected "cps" value was larger than the last. Record the first value under the third unknown if drift resulted in an increase in "corrected cps" of the "B" standard. Program Code:

4, IV, O⅘, W, AC, 42. 3. 426. 393. 7362. 3.+ 423. 636. 3. 636. 3. 637., R, AC, 280, 260, Ans.: 275, 270, 265

5. *Calculation of sample to standard ratio.*

For each unknown, enter the "corrected cps" and then it's adjacent "cps drift." Record the sample to standard ratio under "sam/std." Plot on 0-0.5% or 0.5 to 35% P_2O_5 graphs. Program Code:

5 ¼, W, AC, 96.37., R, AC, 2, 3, Ans.:0.66667

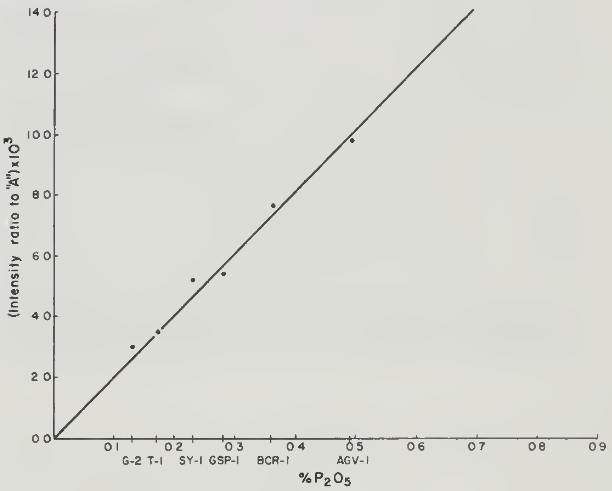


Figure 36. Working curve for P_2O_5 (low phosphate).

NOTES FOR APPENDICES F AND G

1. Detection limit in sample digests is as follows:

   As – 1.0 ppb; Cd – 0.01 ppm; Cd (acid digest) – 0.01 ppm;
   Cu – 0.1 ppm; Pb – 0.1 ppm; Hg – 0.1 ppb; Zn – 0.1 ppm.

2. Detection limit in samples is as follows:

   As – 25.0 ppb; Cd – 0.25 ppm; Cd (acid digest) – 0.02 ppm;
   Cu – 2.5 ppm; Pb – 2.5 ppm; Hg – 2.5 ppb; Zn – 2.5 ppm.

3. '0.0' means either the element is not detected or it is present in quantity less than the specified limit of detection.

4. 'N.D.' means not determined.

5. * Not used in statistical calculations.

6. (For Appendix G only). Detection limit for P is 0.01%.

APPENDIX F

Chemical Analyses of Stream Sediments

LAB. NO.	AS	CD	CU	PB	HG	ZN
	....	(PPM)	....		(PPB)	(PPM)
209/72	0.6	0.2	8.0	3.0	10.0	10.0
210/72	2.0	3.0	5.0	0.0	15.0	32.0
211/72	3.9	5.0	10.0	0.0	28.0	32.0
212/72	0.0	10.0	23.0	15.0	512.0*	65.0
213/72	1.2	0.0	10.0	15.0	28.0	17.0
214/72	1.4	0.4	8.0	15.0	21.0	20.0
215/72	0.5	0.2	5.0	8.0	25.0	20.0
216/72	0.7	0.8	5.0	15.0	13.0	19.0
217/72	1.7	2.5	3.0	8.0	0.0	28.0
218/72	1.0	0.6	8.0	10.0	3.0	32.0
219/72	0.0	0.6	3.0	0.0	13.0	37.0
220/72	4.6	8.4	10.0	13.0	13.0	45.0
221/72	3.3	0.4	3.0	3.0	13.0	10.0
222/72	0.0	0.4	3.0	3.0	10.0	15.0
223/72	0.4	0.0	3.0	3.0	25.0	12.0
224/72	0.3	0.0	8.0	8.0	48.0	25.0
225/72	0.6	0.2	10.0	18.0	3.0	40.0
226/72	0.1	0.0	5.0	8.0	14.0	22.0
227/72	0.1	0.0	5.0	10.0	14.0	27.0
228/72	0.3	0.0	5.0	3.0	14.0	25.0
229/72	0.1	0.0	5.0	13.0	14.0	25.0
230/72	0.1	0.0	3.0	8.0	13.0	27.0
231/72	1.1	0.4	10.0	10.0	18.0	35.0
232/72	0.1	0.1	10.0	15.0	33.0	42.0
233/72	0.1	0.0	5.0	3.0	13.0	19.0
234/72	11.4	22.5	38.0	3.0	31.0	97.0
235/72	7.3	15.4	25.0	8.0	31.0	83.0
236/72	6.8	10.0	18.0	10.0	40.0	60.0
237/72	3.8	4.4	15.0	8.0	50.0	46.0
238/72	5.0	10.0	13.0	13.0	44.0	50.0
239/72	6.5	13.8	20.0	15.0	61.0	72.0
240/72	6.8	12.5	20.0	13.0	45.0	70.0
241/72	9.4	20.0	30.0	13.0	28.0	92.0
242/72	11.8	25.6	38.0	8.0	41.0	117.0*
243/72	9.1	15.4	18.0	8.0	38.0	74.0
244/72	5.0	1.6	18.0	10.0	36.0	40.0
245/72	2.8	0.6	15.0	5.0	39.0	32.0
246/72	3.1	0.6	10.0	5.0	28.0	32.0
247/72	2.8	0.8	15.0	20.0	31.0	38.0
248/72	2.4	0.8	13.0	5.0	28.0	37.0
249/72	5.0	1.2	10.0	5.0	28.0	35.0
250/72	3.6	2.5	13.0	10.0	25.0	37.0
251/72	3.6	2.5	13.0	5.0	38.0	37.0
252/72	1.3	2.5	15.0	8.0	48.0	37.0
253/72	1.4	1.3	13.0	3.0	25.0	37.0
254/72	2.4	0.2	8.0	18.0	38.0	25.0
255/72	1.6	0.2	8.0	18.0	36.0	20.0
256/72	0.3	0.2	5.0	10.0	25.0	29.0
257/72	0.3	0.1	3.0	10.0	28.0	12.0
258/72	2.3	1.3	18.0	15.0	59.0	42.0
259/72	0.7	0.2	3.0	8.0	23.0	12.0
260/72	1.1	0.2	5.0	13.0	30.0	20.0
261/72	3.0	0.1	5.0	13.0	33.0	25.0
262/72	2.4	0.2	8.0	8.0	40.0	35.0
263/72	0.6	0.0	3.0	0.0	21.0	11.0
264/72	0.6	0.2	5.0	0.0	14.0	20.0
265/72	0.5	0.1	8.0	8.0	35.0	34.0
266/72	1.3	0.1	3.0	8.0	28.0	14.0
267/72	0.6	0.0	3.0	0.0	10.0	16.0
268/72	0.6	0.0	3.0	5.0	25.0	27.0
269/72	1.1	0.1	5.0	8.0	38.0	27.0
270/72	0.8	0.0	3.0	3.0	19.0	15.0
271/72	0.4	0.0	3.0	8.0	25.0	15.0
272/72	0.4	0.0	3.0	8.0	10.0	17.0
273/72	0.1	0.0	3.0	5.0	13.0	15.0
274/72	0.8	0.1	5.0	8.0	25.0	27.0
275/72	1.0	0.0	5.0	10.0	20.0	25.0
276/72	2.2	0.1	3.0	8.0	18.0	15.0
277/72	2.3	0.0	8.0	10.0	28.0	30.0
278/72	1.8	0.0	5.0	8.0	15.0	15.0
279/72	0.8	0.0	3.0	0.0	13.0	12.0
280/72	1.4	0.0	5.0	3.0	15.0	19.0
281/72	3.0	0.0	3.0	5.0	18.0	9.0
282/72	3.4	0.1	3.0	3.0	13.0	19.0
283/72	3.0	0.0	3.0	5.0	21.0	17.0
284/72	1.3	0.0	5.0	5.0	10.0	10.0
285/72	1.9	0.0	5.0	8.0	31.0	19.0
286/72	1.0	0.1	5.0	5.0	20.0	12.0
287/72	3.2	0.1	13.0	25.0	60.0	37.0
288/72	1.6	0.6	10.0	13.0	31.0	34.0
289/72	1.3	0.1	5.0	0.0	23.0	15.0
290/72	0.3	0.0	5.0	8.0	18.0	27.0
291/72	1.0	0.3	8.0	8.0	23.0	29.0
292/72	0.5	0.4	5.0	8.0	41.0	20.0
293/72	0.6	0.4	3.0	5.0	40.0	17.0
294/72	0.4	0.1	3.0	3.0	40.0	12.0
295/72	0.2	0.3	3.0	8.0	13.0	17.0
296/72	0.6	0.0	3.0	0.0	28.0	15.0
297/72	1.1	0.0	3.0	3.0	35.0	17.0
298/72	0.4	0.0	3.0	5.0	75.0	22.0
299/72	1.1	0.0	3.0	3.0	46.0	19.0
300/72	1.0	0.0	3.0	5.0	18.0	6.0
301/72	0.7	0.0	3.0	15.0	28.0	14.0
302/72	2.6	0.2	18.0	40.0	88.0	32.0
303/72	1.0	0.1	5.0	10.0	34.0	14.0
304/72	0.8	0.3	5.0	10.0	40.0	22.0
305/72	0.6	0.1	3.0	0.0	21.0	15.0
306/72	1.0	0.3	5.0	15.0	25.0	30.0
572/72	0.5	0.2	3.0	0.0	26.0	10.0
573/72	1.0	0.2	5.0	0.0	10.0	20.0
574/72	1.3	0.3	5.0	3.0	19.0	35.0
575/72	0.3	0.4	3.0	0.0	3.0	10.0
576/72	0.3	0.3	3.0	10.0	3.0	10.0
577/72	1.3	0.1	5.0	102.0*	25.0	17.0
578/72	2.5	0.4	8.0	8.0	28.0	40.0
579/72	2.0	0.6	10.0	18.0	28.0	34.0
580/72	2.8	0.4	8.0	10.0	21.0	35.0
581/72	2.7	0.4	10.0	13.0	25.0	32.0
582/72	1.8	0.4	8.0	10.0	21.0	30.0
583/72	1.0	0.2	5.2	5.0	20.0	59.0
584/72	0.8	0.3	5.0	8.0	38.0	25.0
585/72	0.6	0.2	5.0	5.0	21.0	20.0
586/72	1.3	2.5	5.0	8.0	28.0	25.0
587/72	7.6	12.8	25.0	13.0	38.0	70.0
588/72	7.1	12.6	28.0	15.0	24.0	77.0
589/72	2.4	1.3	5.0	8.0	53.0	25.0
590/72	2.5	1.0	15.0	25.0	48.0	40.0
591/72	2.0	4.2	8.0	8.0	21.0	45.0
592/72	1.2	0.3	3.0	5.0	21.0	25.0
593/72	1.4	0.1	5.0	5.0	31.0	12.0
594/72	5.0	7.8	18.0	18.0	53.0	52.0
595/72	2.8	5.0	8.0	13.0	45.0	35.0
596/72	2.2	0.2	8.0	13.0	58.0	25.0
597/72	1.8	0.1	10.0	8.0	31.0	22.0
598/72	2.8	0.5	15.0	15.0	40.0	35.0
599/72	2.5	0.3	13.0	15.0	46.0	700.0*
600/72	3.5	0.4	10.0	13.0	31.0	31.0
601/72	2.5	0.5	13.0	15.0	56.0	37.0
602/72	3.2	0.3	8.0	15.0	31.0	30.0
603/72	1.8	0.2	18.0	20.0	75.0	40.0
604/72	3.2	0.1	10.0	23.0	88.0	27.0
605/72	1.6	0.3	5.0	13.0	15.0	12.0
606/72	2.1	0.3	5.0	18.0	13.0	10.0
607/72	2.8	2.5	10.0	23.0	19.0	40.0
608/72	3.8	0.2	5.0	18.0	10.0	15.0
609/72	1.3	0.2	3.0	10.0	3.0	9.0
610/72	1.6	0.4	3.0	13.0	0.0	10.0
611/72	0.5	0.4	5.0	8.0	0.0	20.0
612/72	2.0	2.5	3.0	10.0	0.0	30.0
613/72	7.8	12.2	15.0	20.0	21.0	65.0
614/72	0.8	0.6	3.0	10.0	19.0	19.0
615/72	1.0	0.3	3.0	13.0	13.0	15.0
616/72	1.3	1.0	5.0	0.0	3.0	200.0*
617/72	1.4	0.6	5.0	13.0	19.0	22.0
618/72	1.0	0.1	5.0	13.0	8.0	14.0
619/72	2.2	0.2	5.0	15.0	18.0	25.0
620/72	1.8	0.2	5.0	5.0	0.0	22.0
621/72	1.8	0.0	8.0	13.0	0.0	35.0
622/72	1.6	0.0	3.0	3.0	0.0	15.0
623/72	1.1	0.0	0.0	0.0	0.0	6.0
624/72	0.2	0.0	0.0	0.0	0.0	12.0
625/72	1.3	0.4	3.0	0.0	0.0	10.0
626/72	1.0	0.2	3.0	0.0	13.0	12.0
633/72	1.9	0.2	3.0	3.0	0.0	19.0
627/72	1.1	0.3	0.0	20.0	0.0	12.0
628/72	2.7	0.0	0.0	0.0	0.0	12.0
629/72	1.3	0.1	0.0	0.0	0.0	25.0
630/72	2.8	0.2	0.0	0.0	0.0	10.0
631/72	0.5	0.1	0.0	3.0	0.0	15.0
632/72	2.4	0.4	0.0	3.0	0.0	15.0
634/72	1.6	0.3	0.0	3.0	0.0	7.0
635/72	2.0	0.4	0.0	5.0	0.0	15.0
636/72	0.6	0.1	3.0	28.0	7.0	0.0
637/72	0.7	0.1	0.0	3.0	7.0	0.0
638/72	2.5	0.1	0.0	8.0	0.0	5.0
639/72	3.6	0.1	5.0	8.0	0.0	20.0
640/72	2.8	0.2	8.0	13.0	0.0	17.0
641/72	3.5	0.2	15.0	18.0	75.0	45.0
642/72	1.9	0.0	3.0	10.0	0.0	10.0
643/72	3.8	0.5	13.0	28.0	13.0	37.0
644/72	1.3	0.0	5.0	8.0	0.0	12.0
645/72	3.8	0.4	18.0	45.0	15.0	45.0
646/72	1.9	0.1	8.0	15.0	0.0	17.0
647/72	0.9	0.0	5.0	23.0	0.0	11.0
648/72	1.3	0.0	8.0	8.0	0.0	7.0
649/72	1.9	0.0	10.0	10.0	0.0	25.0
650/72	1.4	0.1	10.0	20.0	11.0	27.0
651/72	1.9	0.1	15.0	48.0	0.0	32.0
652/72	1.3	0.0	3.0	10.0	0.0	4.0
653/72	1.6	0.0	3.0	8.0	0.0	6.0
654/72	1.4	0.0	8.0	10.0	0.0	8.0
655/72	1.4	0.0	3.0	8.0	0.0	14.0
656/72	1.0	0.2	8.0	10.0	0.0	14.0
657/72	1.9	0.1	15.0	53.0	33.0	180.0*
658/72	2.9	0.0	3.0	20.0	0.0	17.0
659/72	1.9	0.1	10.0	15.0	0.0	30.0
660/72	0.9	0.0	13.0	15.0	0.0	37.0
661/72	0.9	0.0	5.0	13.0	0.0	17.0
662/72	1.3	0.0	5.0	13.0	0.0	15.0
663/72	1.3	0.0	10.0	0.0	13.0	38.0
664/72	0.4	0.0	5.0	5.0	0.0	25.0
665/72	1.0	0.2	3.0	0.0	0.0	25.0
666/72	1.9	0.7	3.0	0.0	0.0	21.0
667/72	1.0	0.0	15.0	38.0	0.0	34.0
668/72	0.9	0.0	15.0	0.0	19.0	35.0
669/72	2.1	0.0	15.0	0.0	25.0	28.0
670/72	1.4	0.1	5.0	0.0	13.0	33.0
671/72	1.4	0.4	10.0	0.0	15.0	38.0
672/72	1.1	0.2	5.0	0.0	10.0	23.0
673/72	3.0	0.0	3.0	8.0	45.0	15.0
674/72	1.0	0.0	3.0	0.0	30.0	20.0

* Not used in statistical calculations.

APPENDIX G

Chemical Analyses of Bedrocks and Some Stream Sediments

LAB. NO.	AS (PPM)	CD (PPM)	CU (PPM)	PB (PPM)	HG (PPB)	P (%)	ZN (PPM)
93/73	2.5	0.5	30.0	22.3	42.5	N.D.	26.0
94/73	4.0	6.0	17.5	19.0	0.0	N.D.	62.0
95/73	11.5	8.4	27.5	18.8	15.0	N.D.	46.0
96/73	12.5	28.0	25.0	22.5	30.0	0.16	114.0
97/73	14.0	21.5	37.5	20.8	15.0	0.36	72.0
98/73	10.0	17.2	27.5	27.0	0.0	0.31	53.0
99/73	12.5	17.5	25.0	17.5	42.5	0.17	56.0
100/73	11.5	3.6	20.0	20.0	7.5	N.D.	34.0
101/73	27.0	90.0	110.0	27.5	7.5	4.42	214.0
102/73	7.0	9.6	20.0	24.8	8.8	0.54	41.0
103/73	8.5	3.6	17.5	23.8	0.0	N.D.	47.0
104/73	6.0	1.4	27.5	21.0	22.5	N.D.	23.0
105/73	3.0	1.0	17.5	19.8	15.0	N.D.	14.0
106/73	3.0	3.0	22.5	17.5	0.0	N.D.	26.0
107/73	3.5	11.0	25.0	22.5	5.0	0.11	58.0
108/73	2.3	1.2	22.5	24.5	30.0	N.D.	22.0
109/73	4.3	9.6	20.0	18.5	7.5	0.18	43.0
110/73	4.8	1.0	15.0	15.0	7.5	N.D.	17.0
111/73	38.5	22.6	47.5	28.0	7.5	0.52	100.0
112/73	20.8	20.0	25.0	18.8	0.0	0.58	85.0
113/73	11.5	1.6	22.5	19.8	8.8	N.D.	26.0
114/73	17.0	3.6	30.0	21.0	0.0	N.D.	25.0
115/73	29.5	96.0	130.0	26.5	27.5	4.55	235.0
116/73	32.5	50.0	57.5	28.8	7.5	1.98	154.0
117/73	16.5	6.0	20.0	17.8	0.0	N.D.	36.0
118/73	4.5	15.0	15.0	19.3	0.0	0.35	50.0
119/73	9.5	1.4	25.0	18.8	0.0	N.D.	24.0
120/73	6.0	3.6	25.0	21.3	0.0	N.D.	24.0
121/73	3.4	38.5	7.5	27.8	0.0	1.48	107.0
122/73	6.5	1.2	22.5	18.8	0.0	N.D.	19.0
123/73	20.8	3.6	17.5	19.8	60.0	N.D.	32.0
124/73	5.1	5.0	10.0	19.3	72.5	N.D.	24.0
125/73	11.4	5.0	22.5	20.0	72.5	N.D.	52.0
126/73	7.2	0.4	17.5	28.3	0.0	N.D.	10.0
127/73	5.3	1.0	30.0	19.5	20.0	N.D.	21.0

LAB. NO.	AS (PPM)	CD (PPM)	CU (PPM)	PB (PPM)	HG (PPB)	P (%)
163/73	19.3	8.0	37.5	20.0	0.0	0.32
164/73	9.8	2.9	15.0	18.8	45.0	N.D.
165/73	17.5	0.6	35.0	22.5	0.0	N.D.
166/73	5.3	0.6	20.0	16.5	2.5	N.D.
167/73	19.5	348.0	122.5	24.0	17.5	11.54
168/73	31.5	348.0	162.5	27.0	140.0	15.01
169/73	22.0	3.8	37.5	18.8	0.0	N.D.
170/73	12.5	11.0	32.5	16.8	0.0	0.24
171/73	18.8	52.0	74.0	27.0	0.0	1.94
172/73	1.5	5.0	12.5	23.0	5.0	N.D.
173/73	10.5	6.5	25.0	22.0	0.0	0.31
174/73	0.8	0.1	32.8	20.8	11.3	N.D.
175/73	9.0	5.3	20.0	18.3	0.0	N.D.
176/73	0.0	0.2	5.0	15.5	0.0	N.D.
177/73	27.0	150.0	124.5	22.5	0.0	9.21
178/73	5.8	18.6	15.0	18.0	0.0	0.57
179/73	17.0	10.0	22.5	18.0	5.0	0.51
180/73	2.6	0.8	3.0	12.8	5.0	N.D.
181/73	65.0	14.0	47.5	35.0	31.3	0.57
182/73	5.8	9.0	22.5	18.5	0.0	0.60
183/73	4.8	1.8	10.0	23.0	5.0	N.D.
184/73	7.0	6.0	45.0	18.8	0.0	N.D.
185/73	4.8	1.0	25.0	15.8	0.0	N.D.
186/73	14.8	0.8	20.0	24.3	2.5	N.D.
187/73	2.1	0.2	7.5	18.0	0.0	N.D.
188/73	14.8	10.0	30.0	18.0	45.0	0.17
189/73	4.8	1.0	27.5	13.8	5.0	N.D.
190/73	4.8	1.0	26.3	20.0	77.5	N.D.
191/73	1.4	0.1	23.0	28.0	0.0	N.D.
192/73	17.5	1.1	45.0	20.0	21.3	N.D.
193/73	3.2	0.3	5.0	15.0	0.0	N.D.
194/73	4.8	0.6	2.5	13.8	0.0	N.D.
195/73	8.0	0.6	25.0	11.3	0.0	N.D.
196/73	20.0	3.0	24.0	22.5	77.5	N.D.
197/73	3.0	2.4	7.5	15.0	0.0	N.D.

LAB. NO.	AS (PPM)	CD (PPM)	CU (PPM)	PB (PPM)	HG (PPB)	P (%)	ZN (PPM)
128/73	15.0	12.0	22.5	22.5	0.0	0.13	74.0
129/73	20.0	20.0	21.3	21.3	12.5	0.57	90.0
130/73	9.5	19.4	15.0	29.3	0.0	N.D.	58.0
131/73	72.0	4.0	27.5	47.8	160.0	N.D.	48.0
132/73	5.1	1.0	20.0	21.8	0.0	N.D.	26.0
133/73	4.8	3.8	27.5	25.0	5.0	N.D.	28.0
134/73	5.3	2.4	30.0	23.3	0.0	N.D.	31.0
135/73	11.8	3.0	45.0	21.8	5.0	N.D.	54.0
136/73	10.0	6.0	32.5	21.8	5.0	N.D.	64.0
137/73	3.2	0.2	12.5	20.0	5.0	N.D.	10.0
138/73	0.4	0.0	30.0	18.3	5.0	N.D.	10.0
139/73	2.5	0.0	7.5	16.8	15.0	N.D.	8.0
140/73	5.7	2.2	15.0	19.3	15.0	N.D.	30.0
141/73	2.3	0.3	17.5	16.0	10.0	N.D.	16.0
142/73	1.1	17.0	5.8	20.0	25.0	0.30	58.0
143/73	7.0	6.4	17.3	30.0	0.0	N.D.	48.0
144/73	2.1	1.0	10.0	16.3	10.0	N.D.	32.0
145/73	9.0	1.8	12.5	17.3	0.0	0.28	20.0
146/73	4.3	5.0	25.0	19.5	0.0	N.D.	33.0
147/73	6.3	8.0	7.5	28.5	0.0	0.21	42.0
148/73	17.5	0.9	22.5	18.0	5.0	N.D.	25.0
149/73	17.0	14.0	37.5	22.5	5.0	0.08	58.0
150/73	16.0	3.6	17.5	19.3	0.0	N.D.	38.0
151/73	5.3	6.0	25.0	17.0	0.0	N.D.	39.0
152/73	14.3	10.0	30.0	24.5	57.5	N.D.	77.0
153/73	5.1	8.0	20.0	19.8	5.0	0.26	44.0
154/73	9.0	1.0	12.5	16.5	50.0	N.D.	19.0
155/73	19.3	32.8	32.5	25.3	5.0	1.22	118.0
156/73	10.0	15.4	25.0	18.8	0.0	0.14	55.0
157/73	14.3	10.0	25.0	16.0	5.0	0.07	62.0
158/73	8.5	5.7	23.0	15.0	0.0	N.D.	37.0
159/73	14.8	166.0	150.0	26.3	11.3	7.72	275.0
160/73	18.5	121.0	132.5	25.0	17.5	7.29	245.0
161/73	0.5	0.8	12.5	17.0	5.0	N.D.	21.0
162/73	27.5	27.6	57.5	24.5	0.0	0.33	103.0

LAB. NO.	AS (PPM)	CD (PPM)	CU (PPM)	PB (PPM)	HG (PPB)	P (%)
198/73	8.5	3.1	22.0	10.0	0.0	N.D.
199/73	5.3	3.0	10.0	15.0	0.0	N.D.
200/73	10.5	10.0	15.0	18.8	5.0	0.06
201/73	6.3	7.3	25.0	15.5	2.5	0.07
202/73	7.0	7.6	12.5	15.0	0.0	0.07
203/73	12.8	10.0	22.5	21.8	40.0	0.07
204/73	1.0	0.5	12.5	14.0	138.0	N.D.
205/73	13.3	16.6	22.5	22.5	40.0	0.07
206/73	6.3	32.2	33.3	17.5	0.0	0.99
207/73	3.5	0.5	7.5	15.8	0.0	N.D.
208/73	4.3	0.5	20.0	27.8	70.0	N.D.
209/73	2.3	0.8	7.5	20.0	47.5	N.D.
210/73	3.2	5.0	7.5	16.3	0.0	N.D.
211/73	8.0	3.0	17.5	18.0	62.5	N.D.
212/73	9.8	13.1	20.3	20.0	40.0	0.07
213/73	7.0	4.0	10.0	16.5	47.5	N.D.
214/73	7.5	0.5	10.0	16.3	0.0	N.D.
215/73	3.0	7.2	2.5	14.5	0.0	0.31
216/73	12.8	2.8	10.0	15.0	92.5	N.D.
217/73	9.8	2.3	37.5	30.0	0.0	N.D.
218/73	12.3	2.0	15.0	18.8	0.0	N.D.
219/73	10.0	10.6	20.0	15.0	0.0	0.37
220/73	9.8	0.1	7.5	23.0	0.0	N.D.
221/73	4.3	0.8	18.5	21.5	7.5	N.D.
222/73	12.8	1.2	9.3	22.0	0.0	N.D.
223/73	6.3	0.2	13.8	21.0	0.0	N.D.
224/73	14.3	1.0	10.0	20.8	0.0	N.D.
225/73	8.5	0.3	7.5	18.8	0.0	N.D.
226/73	12.3	0.3	7.0	16.8	30.0	N.D.
227/73	7.0	0.0	12.8	20.0	55.0	N.D.
228/73	3.0	0.1	9.8	20.0	0.0	N.D.
229/73	19.3	0.0	15.5	22.0	55.0	N.D.
230/73	4.8	0.2	11.8	19.3	62.5	N.D.
231/73	2.6	0.2	8.0	19.0	0.0	N.D.
232/73	2.6	0.4	7.5	17.0	40.0	N.D.

APPENDIX G (continued)
Chemical Analyses of Bedrocks and Some Stream Sediments

LB.	AS	CD	CU	PB	HG	P	ZN
O.	....	....	(PPM)	....	(PPB)	(%)	(PPM)
2/73	10.5	0.2	17.5	20.5	0.0	N.D.	24.0
2/73	3.5	0.0	11.0	19.3	25.0	N.D.	24.0
2/73	18.8	1.0	13.8	24.5	30.0	N.D.	34.0
2/73	9.0	1.8	13.3	25.3	7.5	N.D.	49.0
2/73	3.5	1.0	10.0	18.8	7.5	N.D.	14.0
2/73	2.6	1.0	8.3	20.0	0.0	N.D.	23.0
2/73	4.8	0.5	13.0	25.5	0.0	N.D.	31.0
2/73	8.5	7.2	16.3	22.5	7.5	0.28	46.0
2/73	6.3	0.6	37.5	15.3	62.5	N.D.	20.0
2/73	4.0	0.8	11.5	23.8	0.0	N.D.	25.0
2/73	2.6	0.1	14.8	23.5	7.5	N.D.	44.0
2/73	20.0	0.8	25.8	30.3	25.0	N.D.	23.0
2/73	21.0	0.1	14.8	25.0	25.0	N.D.	20.0
2/73	4.8	0.0	15.5	25.5	15.0	N.D.	25.0
2/73	7.0	2.5	22.5	11.8	55.0	N.D.	26.0
2/73	7.0	1.5	16.0	22.5	25.0	N.D.	33.0
2/73	7.0	0.1	18.8	25.8	15.0	N.D.	21.0
2/73	7.0	0.1	13.8	26.0	15.0	N.D.	27.0
2/73	9.0	0.5	20.0	19.3	7.5	N.D.	28.0
2/73	5.3	0.1	9.0	18.5	0.0	N.D.	13.0
2/73	3.0	0.8	15.8	24.8	7.5	N.D.	28.0
2/73	4.3	19.4	20.5	22.5	0.0	N.D.	64.0
2/73	4.3	2.0	17.3	22.5	15.0	N.D.	36.0
2/73	1.5	1.0	16.8	26.0	7.5	N.D.	33.0
2/73	7.0	0.5	9.5	25.0	7.5	N.D.	23.0
2/73	4.8	0.1	12.8	20.3	15.0	N.D.	21.0
2/73	14.8	0.6	9.5	21.3	15.0	N.D.	27.0
2/73	12.5	23.3	32.5	20.0	0.0	0.08	81.0
2/73	10.5	0.6	30.3	24.3	0.0	N.D.	30.0
2/73	3.5	0.0	7.5	18.8	0.0	N.D.	26.0
2/73	3.0	0.0	5.0	17.3	15.0	N.D.	12.0
2/73	0.4	0.0	12.0	15.0	0.0	N.D.	23.0
2/73	1.2	0.0	23.0	16.8	0.0	N.D.	27.0
2/73	1.5	0.8	11.8	23.5	15.0	N.D.	30.0
2/73	9.0	0.1	12.5	25.0	55.0	N.D.	25.0

LAB.	AS	CD	CU	PB	HG	P	ZN
NO.	....	....	(PPM)	....	(PPB)	(%)	(PPM)
303/73	5.3	0.5	17.5	17.8	60.0	N.D.	28.0
304/73	1.0	1.0	23.3	17.5	237.5	N.D.	42.0
305/73	2.4	0.8	13.3	17.5	0.0	N.D.	30.0
306/73	2.2	0.0	14.3	15.8	3.8	N.D.	34.0
307/73	6.2	8.3	22.0	16.8	0.0	0.30	46.0
308/73	12.9	16.1	25.5	20.0	0.0	N.D.	51.0
309/73	7.2	8.0	29.8	21.0	20.0	0.21	61.0
310/73	5.8	2.4	20.5	15.3	3.8	N.D.	52.0
311/73	66.0	603.2	127.5	25.0	230.0	17.11	437.0
312/73	69.0	625.6	133.0	25.0	267.5	17.11	468.0
313/73	19.0	56.0	55.6	25.0	147.5	2.97	129.0
314/73	4.0	512.0	111.5	30.0	3.8	15.32	385.0
315/73	10.0	600.0	160.0	30.0	75.0	16.85	455.0
316/73	26.5	324.8	155.0	27.5	15.0	14.27	285.0
317/73	10.0	321.6	145.0	32.5	180.0	14.36	278.0
318/73	13.0	260.0	114.3	30.0	7.5	12.00	253.0
319/73	14.3	21.5	40.6	25.0	0.0	0.22	72.0
320/73	13.0	35.0	50.0	20.0	3.8	0.20	94.0
321/73	14.5	2.6	36.0	35.0	3.8	0.22	60.0
322/73	6.0	3.0	35.8	35.0	20.0	0.28	49.0
323/73	8.0	2.0	26.8	20.0	0.0	0.10	29.0
324/73	12.0	154.0	195.0	20.0	3.8	7.11	265.0
325/73	4.3	130.9	150.0	20.0	3.8	6.63	255.0
326/73	57.0	25.0	36.8	32.5	0.0	0.55	105.0
327/73	64.0	21.0	34.8	32.5	0.0	0.38	99.0
328/73	19.0	12.0	20.8	25.0	3.8	0.20	80.0
329/73	24.0	18.2	28.3	20.0	0.0	0.35	96.0
330/73	36.0	60.0	97.5	27.5	60.0	2.73	173.0
331/73	54.0	60.0	95.0	20.0	7.5	2.92	147.0
332/73	7.0	0.6	8.8	15.0	0.0	0.06	7.0
333/73	16.0	16.6	17.0	20.0	0.0	0.27	65.0
334/73	26.0	73.9	87.5	32.5	0.0	3.70	165.0
335/73	23.5	53.5	28.8	35.0	0.0	1.94	129.0
336/73	12.0	34.3	7.3	62.5	5.0	0.99	88.0
337/73	14.5	35.7	6.5	32.5	5.0	1.45	89.0

LA.	AS	CD	CU	PB	HG	P	ZN
N.	....	....	(PPM)	....	(PPB)	(%)	(PPM)
26/73	1.9	0.1	17.5	22.0	40.0	N.D.	24.0
26/73	0.2	0.0	14.8	19.3	7.5	N.D.	15.0
27/73	2.3	0.2	5.3	19.0	0.0	N.D.	18.0
27/73	3.6	0.4	8.3	20.3	7.5	N.D.	31.0
27/73	2.9	0.1	15.8	26.3	15.0	N.D.	24.0
27/73	5.6	0.2	16.8	26.5	20.0	N.D.	26.0
27/73	5.1	2.3	11.0	14.0	0.0	N.D.	17.0
27/73	3.1	4.0	25.0	30.0	0.0	N.D.	30.0
27/73	3.1	14.6	30.0	20.0	3.8	0.21	78.0
27/73	31.8	100.0	132.0	25.0	175.0	4.65	238.0
27/73	3.3	0.5	24.3	19.5	0.0	N.D.	30.0
27/73	2.5	1.8	20.0	13.0	0.0	N.D.	18.0
28/73	0.7	0.0	9.3	17.3	0.0	N.D.	20.0
28/73	1.9	0.0	13.3	20.3	0.0	N.D.	23.0
28/73	2.5	0.0	13.3	16.3	0.0	N.D.	25.0
28/73	3.1	0.3	31.8	15.5	0.0	N.D.	25.0
28/73	6.6	0.4	10.8	14.3	0.0	N.D.	14.0
28/73	9.5	16.4	45.3	19.0	0.0	0.61	55.0
28/73	1.1	0.0	24.0	19.3	0.0	N.D.	31.0
28/73	2.3	0.0	3.0	18.3	0.0	N.D.	13.0
28/73	3.1	0.1	3.8	16.5	0.0	N.D.	12.0
28/73	0.9	0.0	31.3	15.8	220.0	N.D.	14.0
29/73	1.9	0.0	15.0	23.0	560.0	N.D.	33.0
29/73	2.1	0.0	7.5	18.5	435.0	N.D.	23.0
29/73	0.7	0.0	18.5	11.8	0.0	N.D.	26.0
29/73	2.7	0.5	8.0	14.3	60.0	N.D.	21.0
29/73	1.4	0.0	3.0	14.8	0.0	N.D.	21.0
29/73	4.0	17.7	27.3	20.0	0.0	0.81	62.0
29/73	13.3	0.6	28.8	15.5	0.0	N.D.	28.0
29/73	12.5	2.7	38.3	21.8	0.0	N.D.	58.0
29/73	17.3	0.1	17.5	17.8	0.0	N.D.	26.0
29/73	2.0	1.5	15.3	17.3	0.0	N.D.	43.0
30/73	1.0	0.1	1.5	14.3	75.0	N.D.	8.0
30/73	0.5	0.1	13.8	18.0	3.8	N.D.	22.0
30/73	2.5	0.1	2.5	16.5	0.0	N.D.	9.0

LAB.	AS	CD	CU	PB	HG	P	ZN
NO.	....	....	(PPM)	....	(PPB)	(%)	(PPM)
338/73	26.0	67.5	49.5	20.0	5.0	3.25	157.0
339/73	17.0	2.0	22.0	20.0	300.0	0.12	21.0
340/73	12.5	2.6	22.8	20.0	247.5	0.21	26.0
341/73	8.5	5.0	7.5	22.5	157.5	0.09	36.0
342/73	17.0	11.0	9.8	32.5	157.5	0.15	76.0
343/73	8.5	23.0	21.3	25.0	5.0	0.74	70.0
344/73	8.5	20.2	12.3	32.5	5.0	0.64	60.0
345/73	17.0	4.0	25.5	30.0	90.0	0.08	35.0
346/73	23.5	55.0	110.0	27.5	20.0	2.54	158.0
347/73	21.0	59.0	97.5	20.0	25.0	2.49	164.0
348/73	4.5	24.0	26.8	25.0	20.0	0.76	83.0
349/73	16.0	151.2	135.0	30.0	82.5	9.92	255.0
350/73	18.5	154.7	165.0	30.0	62.5	10.43	262.0
351/73	26.0	34.8	65.0	40.0	97.5	1.56	120.0

APPENDIX H

Precision and Accuracy of the Analytical Techniques

The precision of the analytical techniques developed in this project was tested to determine the aggregate errors resulting from sample splitting, digesting, diluting, and analyzing by analytical instruments. Ten replications of samples 607/72 and 167/73 were digested and run as unknowns at various times during analyses. Similarly, N.B.S. 120a was digested in ten replications and run for phosphorous. The results of this precision test and the standard deviations are given in Table 9.

To check the accuracy of the method of analyses, U.S. Geological Survey standard rock samples G–2 and GSP–1 were digested four times, and Canadian Association of Applied Spectroscop standard rock sample Sulphide Ore was digested two times analyzed several times as the unknown with the other samp Unfortunately, these rock standards did not cover the accu of cadmium determination. However, cadmium was analy two times from two separate digests for each sample. The res seem to be in good agreement with each other, and the repr cibility seems to be very good. As a whole, the precisio sufficient for these samples, and the accuracy of the techni is very good.

Table 9. Precision tests for ten replications of samples 607/72, 167/73, and N.B.S. 120a.

Element	n	#607/72 (Stream Sediment)		#167/73 (Phosphatic Pellets)		N.B.S. 120 a (Phosphatic Limestone	
		Mean x	Standard Deviation s	Mean x	Standard Deviation s	Mean x	Standard Deviati s
As	10	3.8 ppm	3.6 ppm	19.5 ppm	3.2 ppm	-	-
Cd	10	2.5 ppm	1.2 ppm	348.0 ppm	1.0 ppm	-	-
Cu	10	10.0 ppm	3.7 ppm	122.5 ppm	2.7 ppm	-	-
Pb	10	23.0 ppm	2.4 ppm	24.0 ppm	1.5 ppm	-	-
Hg	10	19.0 ppb	10.8 ppb	17.5 ppb	8.5 ppb	-	-
P	10	-	-	-	-	16.42%	0.12%
Zn	10	40.0 ppm	2.1 ppm	11.5 ppm	2.0 ppm	-	-

Table 10. Accuracy of arsenic, copper, lead, mercury, and zinc analyses.

Standard Rocks	Reference	As (ppm)		Cu (ppm)		Pb (ppm)		Hg (ppb)		Zn (ppm)	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Ran
U.S.G.S. G-2	Majmundar	1.2(8)[1]	0.9-1.5	13(8)	10-15	27(8)	24-33	46(8)	46-47	80(8)	74-
	Flanagan[2]	0.98(4)	0.8-1.2	11(24)	<2-17	29(18)	15-43	47(5)	29-50	83(15)	42-
U.S.G.S. GSP-1	Majmundar	1.35(6)	1.0-1.75	32(8)	28-36	48(8)	42-58	17(8)	16-17	110(8)	96-
	Flanagan	1.25(4)	1.1-1.4	34(25)	15-54	51(19)	14-80	17(5)	15-41	114(16)	54-
C.A.A.S. Sulphide Ore	Majmundar	300(4)	275-350	8273(6)	8180-8360	256(13)	236-274	NO DATA		221(13)	202
	Webber[3]	424(8)	250-500	8291(16)	4000-12000	248(11)	200-310	NO DATA		298(8)	160

Notes:
1. Number in parentheses represents number of readings. Four separate digestions were made for USGS G-2 and GSP-1, and two separate digestions were made for C.A.A.S. Sulphide Ore.
2. Flanagan, F.J. (1973).
3. Webber, G.R. (1965).

APPENDIX I

Statistical Treatment of Data

he results of chemical analyses of arsenic, cadmium, copper, lead, mercury, phosphorous, and zinc are recorded in Appendices F and G. The very highly anomalous values, which are marked with an asterisk (*) in the tables, were considered to be random and were not considered in statistical calculations. All the calculations are based on the 201 stream sediment and 259 bedrock samples. The results of analyses of cadmium and phosphorous in samples from localities other than those in the area under investigation is given in Table 6.

hese data were plotted on the maps at the respective sample locations by plotting one element on each map (Figures 5 through 17).

istograms clearly illustrate the effect of the detection limit of the analytical method. However, histograms can be misleading because they are strongly affected by slight changes in class intervals. Histograms and cumulative frequency curves, drawn from the same data, can be compared easily. Cumulative frequency distribution curves were drawn for all the elements analysed in the present study by the graphical methods described by Lepeltier (1969). Frequencies were calculated from lowest to highest values, plotted against concentration on log–probability paper (Figures 37 through 49), and then used to calculate statistical parameters (Table 11). Histograms were constructed (Figures 50 through 62) plotting the percentage of frequencies against element concentration on 2– or 3–cycle, semi-log paper. Statistical parameters were compared with crustal and soil abundances.

here are two reasons for drawing the cumulative frequency curve: to check whether it fits a lognormal distribution and, if it does, to estimate the basic parameters, background (b), coefficients of deviation (s', s) and threshold level (t). The background gives the average concentration levels of the elements in a given setting. A single straight line shows a single population, lognormally distributed. In such a case, the background concentration is indicated by the intersection of the straight line with the 50 percent ordinate, illustrated in Figure 48 for zinc in stream sediment samples. In the case of a perfect frequency distribution curve, the background, calculated in this way, corresponds to the mode and median values and is the geometric mean of the results.

y projecting the intersection of the 84 percent ordinate with the straight line, a value is obtained which is divided by the geometric mean value to get the geometric deviation (s'). The logarithm of this value is the coefficient of deviation (s). Coefficient of deviation expresses the scatter of the values around (b) and corresponds to the spread of the values and their range, from the lowest to the highest.

fter obtaining the background and coefficients of deviation the third important parameter, the threshold level (t), can be calculated by the following formula:

$\log t = (\log b) + 2\,s$, Where t is threshold level; b, the background, and s, the coefficient of deviation.

The threshold level represents an upper limit, above which the values are considered anomalous. This can be read directly from the graph as the abscissa of the intersection of the distribution line with the 97.5 percent ordinate. Values greater than this were considered anomalous.

The procedure for calculating the statistical parameters can be illustrated easily by taking the example of zinc in stream sediment samples. In this study, zinc represents the perfect lognormal distribution. The background calculated in this case corresponds to the mode and median values and is the geometric mean of the results. This geometric mean is considered to be more significant and a more stable statistic than the arithmetic mean. It is less subject to change with the addition of new data and less affected by high values. For example, the geometric mean of cadmium in bedrocks is 5.2, and the arithmetic mean is 27.2, which is greater than the threshold level. In the case of zinc, the geometric mean, calculated by the intersection of the straight line with the 50 percent ordinate, was 21.5 ppm Zn.

If (b) is the median value and (s) the standard deviation, then 68 percent of the population will fall between b–s and b+s; and 97.5 percent of the population will fall between b–2s and b+2s. As 68 percent of the pcpulation falls between b–s and b+s, 32 percent of the population falls outsides this limit (i.e. 16 percent of the values fall above b+s and 16 percent below b–s). In Figure 48, the values b–s and b+s were obtained by projecting the intersection of straight line with the ordinate 16 percent and 84 percent on the abscissa. As all the frequency curves were drawn in logarithmic scale, the ratios were taken into consideration rather than the absolute values. Thus, points P (at 84 percent ordinate) and A were determined. OA is the geometrical expression of the deviation and is known as geometric deviation (s'), which is a factor obtained by dividing the value read at A by the value at 0 (1.86 in the case of zinc). Then dividing or multiplying the background value (21.5) by the geometric deviation (1.86), the upper and lower limits respectively of a range that encompasses 68 percent of the population were calculated as 11.5 to 40 ppm Zn. Further, dividing or multiplying by the squares of the geometric deviation provides a range encompassing 97.5 percent of the population and extending from 6.2 to 74 ppm Zn.

The coefficient of deviation (s) is 0.27, obtained by reading the logarithmic of geometric deviation (s'), 1.86 for zinc. The third important parameter, threshold level, is the function of (b) and (s). In case of symetrical distribution (normal or log normal), 97.5 percent of the population falls between b+2s and b–2s. Thus, this upper limit was read directly from the cumulative frequency curve as the abscissa of the intersection of the distribution line with 97.5 percent ordinate and was calculated by using the preceeding formula. The threshold level for zinc was found to be 74 ppm Zn, taken from the curve as well as calculated from the formula.

In cases where a complex population was sampled (Figures 39 through 42, 46, and 47), there were two distinct straight lines with different slopes, one representing the lognormal population, the other the probable anomalous population. The thresholds levels in such cases were taken at the break in slope. For example, in the case of Cd (in both, stream sediment and bedrock samples), the data show a positive skew in the direction of the high values, and the data for Cu (in stream sediment samples) show a negative skew in the direction of the low values. In such statistical studies the coefficients of deviation are very important. It is possible for two populations to have the same background, but they will have different threshold levels if their coefficients of deviation are different.

In the case of Cd and Cu, the cumulative frequency distr tion curves show two breaks, and the histograms give do peaks. This dual distribution suggests the presence of two tinct populations. These curves also could be interpreted splitting the data at a value taken around the place where break occurred, separating the total population into two pa and drawing two separate curves. In such a procedure, the co cients of deviation and threshold levels may be calculated s rately for both populations.

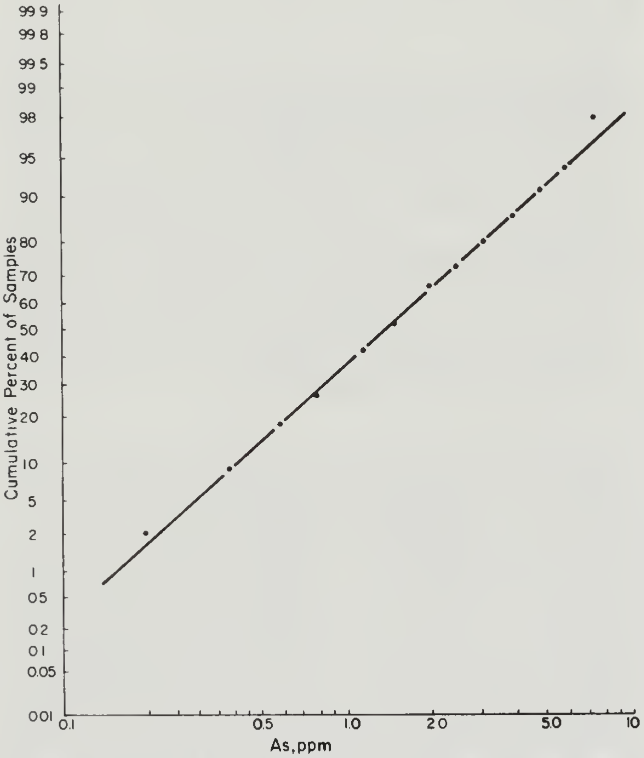


Figure 37. Cumulative frequency distribution for arsenic in stream sediments (N= 189).

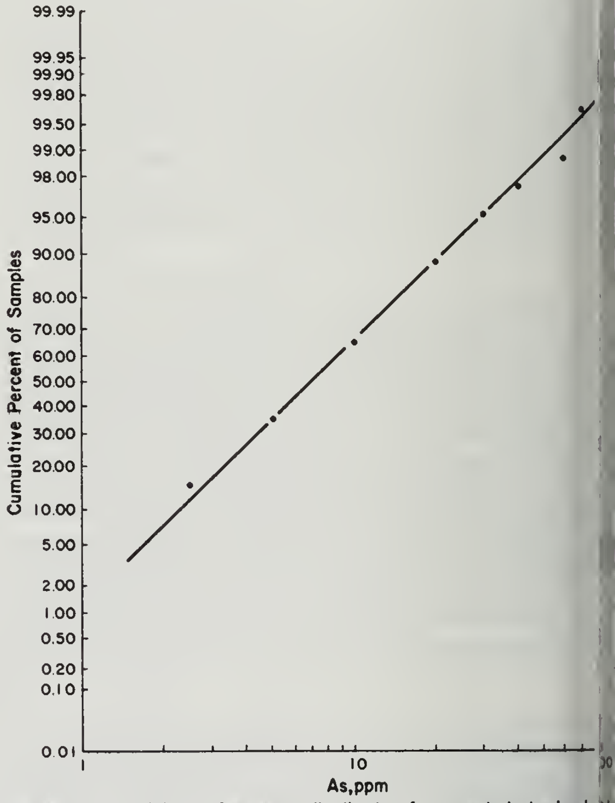


Figure 38. Cumlulative frequency distribution for arsenic in bedrock N = 258).

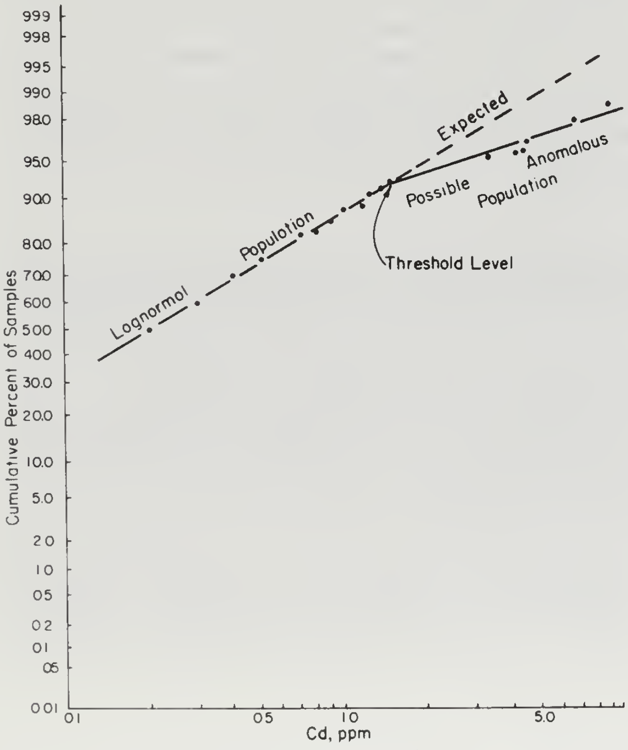


Figure 39. Cumulative frequency distribution for cadmium in stream sediments (N= 156).

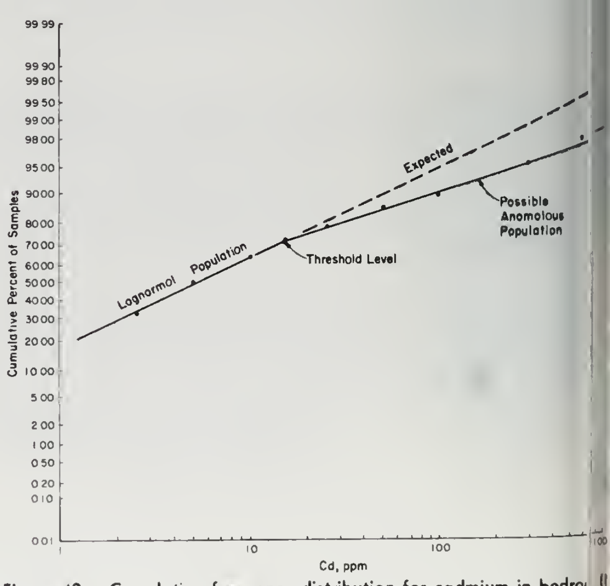
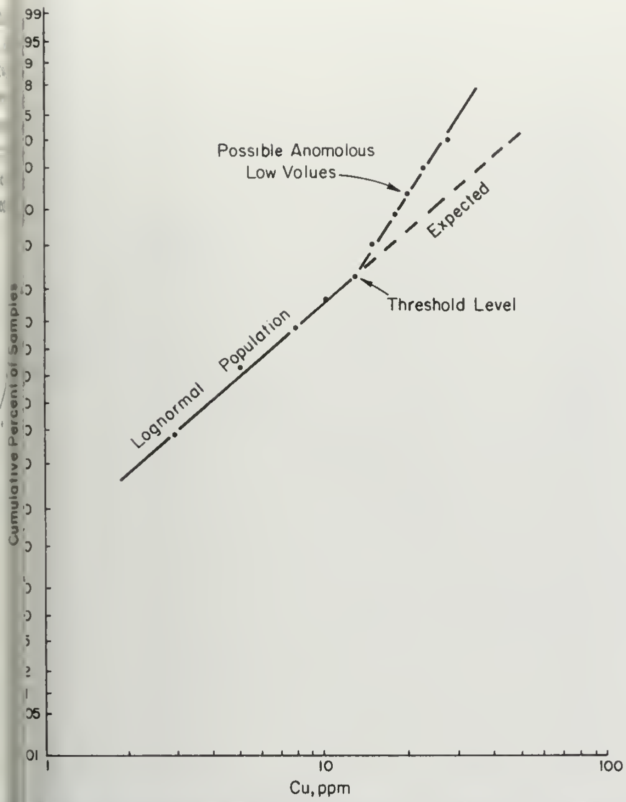


Figure 40. Cumulative frequency distribution for cadmium in bedro = 235).



Fi e 41. Cumulative frequency distribution for copper in stream sedi– mes (N= 189).

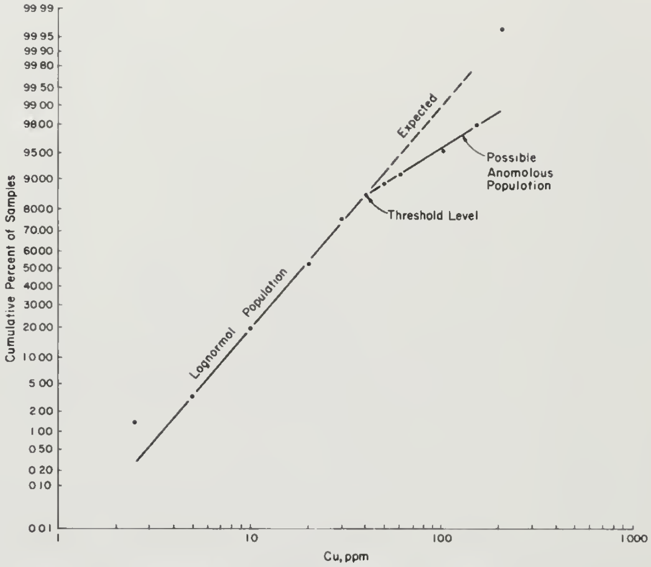


Figure 42. Cumulative frequency distribution for copper in bedrocks (N = 259).

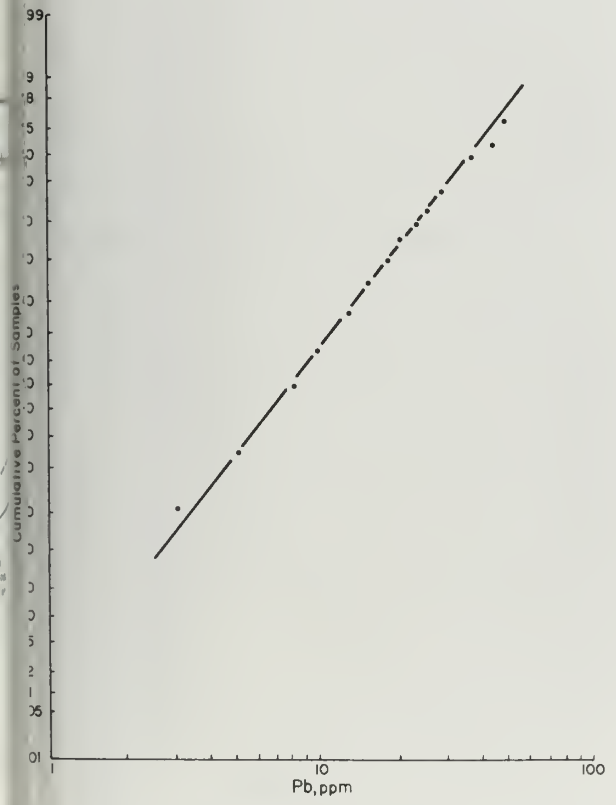


Fig 43. Cumulative frequency distribution for lead in stream sediments (N 167).

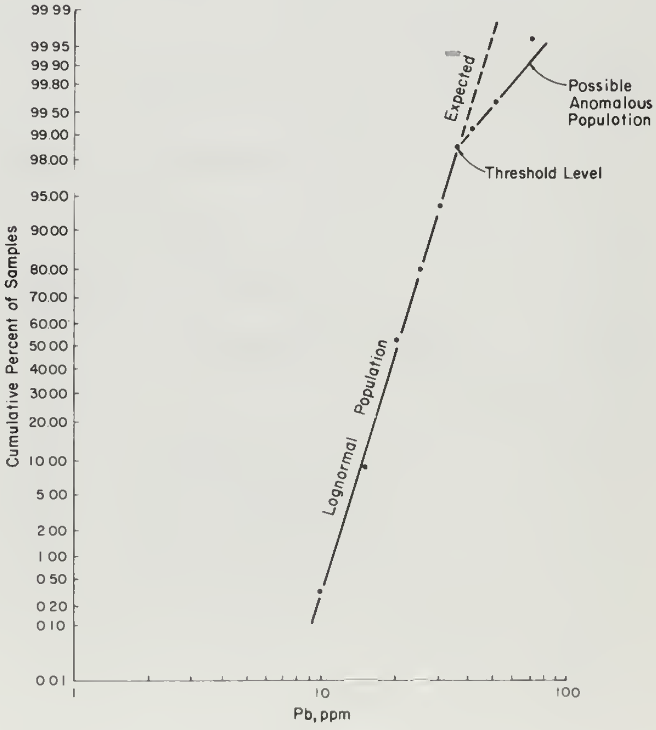


Figure 44. Cumulative frequency distribution for lead in bedrocks (N= 259).

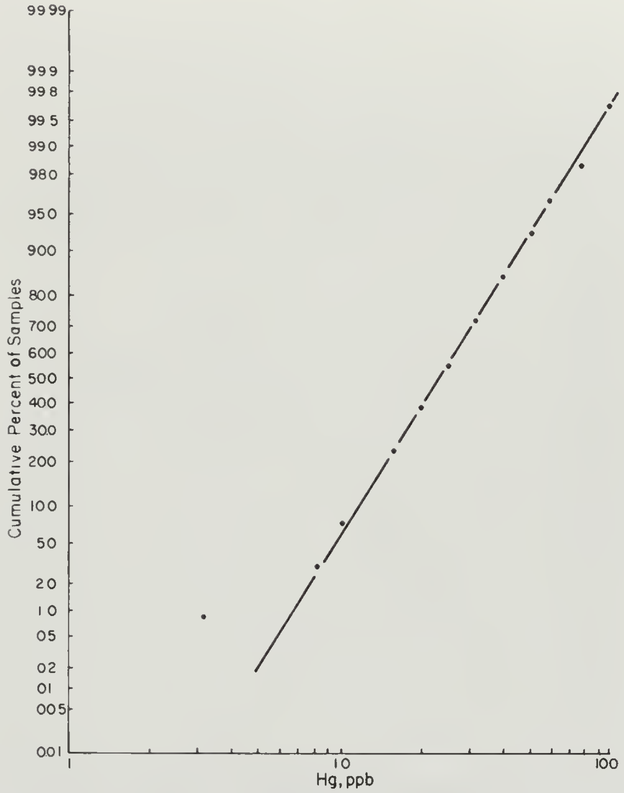


Figure 45. Cumulative frequency distribution for mercury in stream sediments (N= 153).

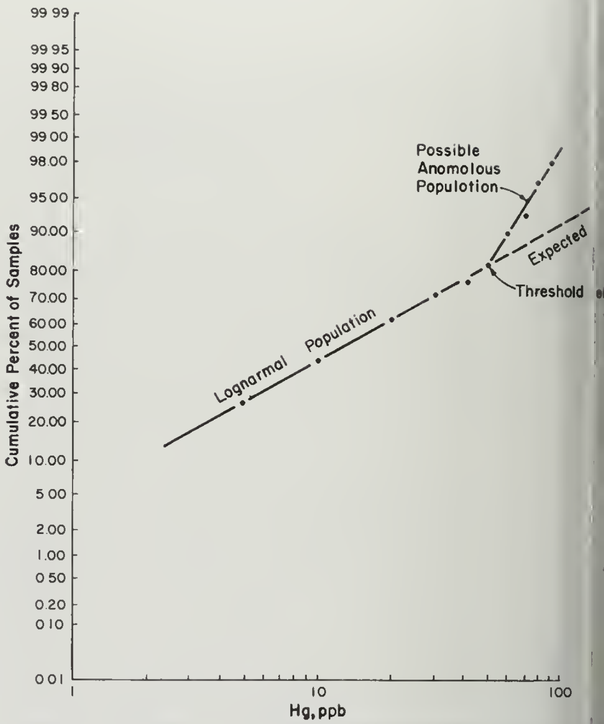


Figure 46. Cumulative frequency distribution for mercury in bedrock N = 135).

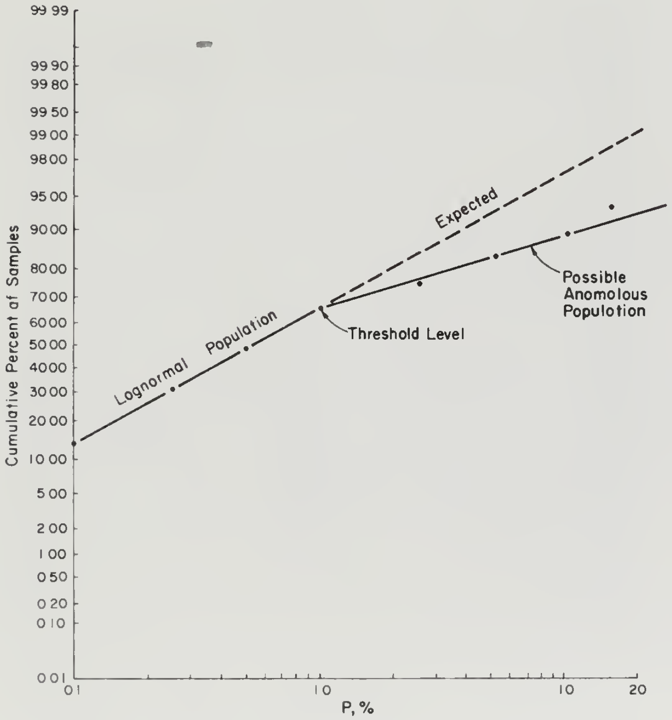


Figure 47. Cumulative frequency distribution for phosphorus in bedrocks (N = 97).

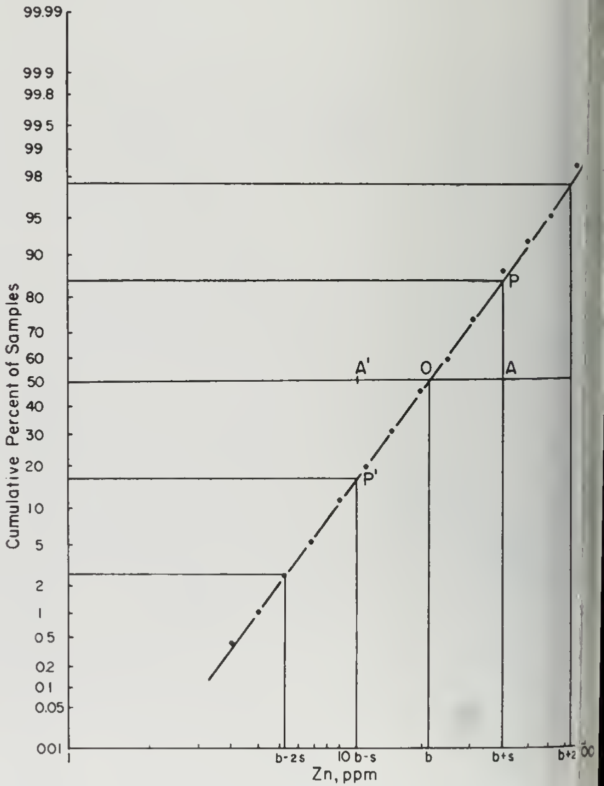


Figure 48. Cumulative frequency distribution for zinc in stream sediments (N= 198).

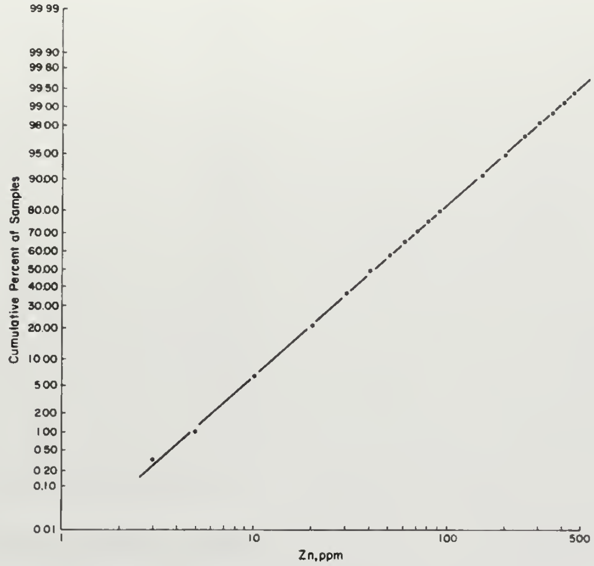


Figure 49. Cumulative frequency distribution for zinc in bedrocks (N= 259).

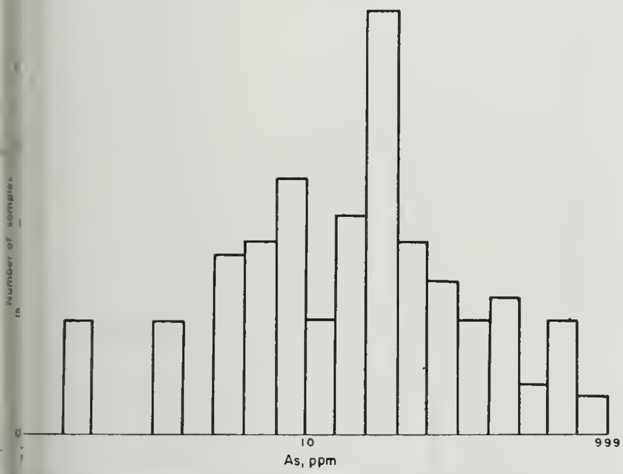


Fig 50. Histogram for arsenic in stream sediments.

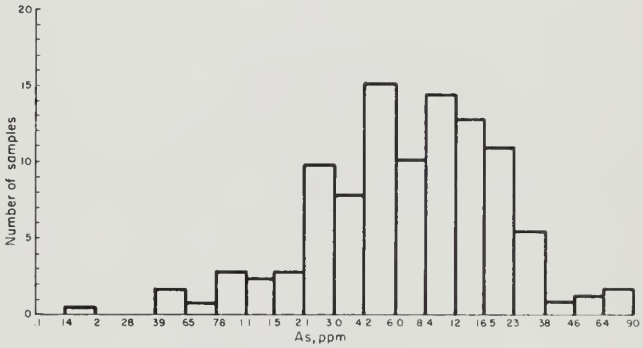


Figure 51. Histogram for arsenic in bedrocks.

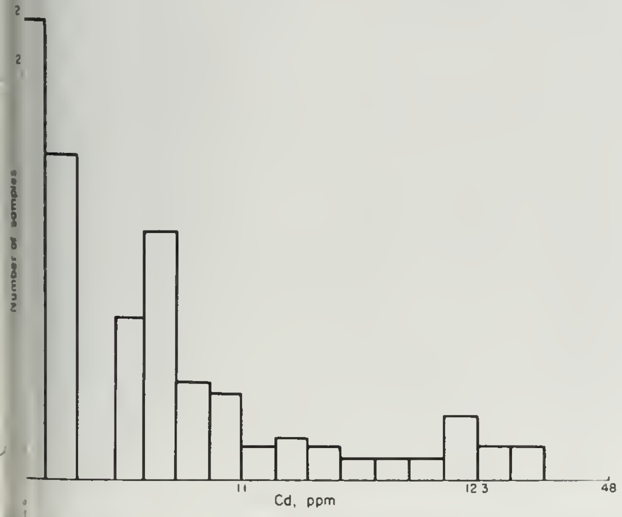


Fig 52. Histogram far cadmium in stream sediments.

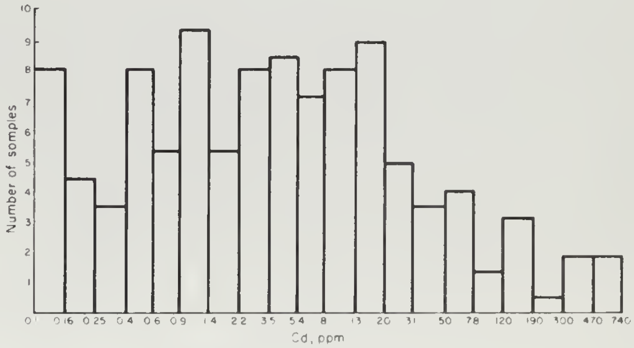


Figure 53. Histogram far cadmium in bedracks.

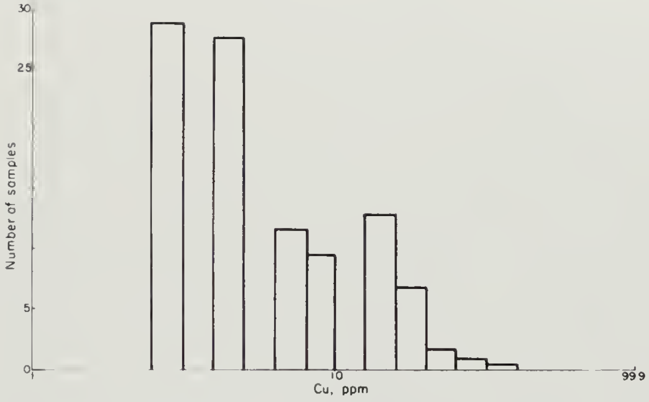


Figure 54. Histogram for copper in stream sediments.

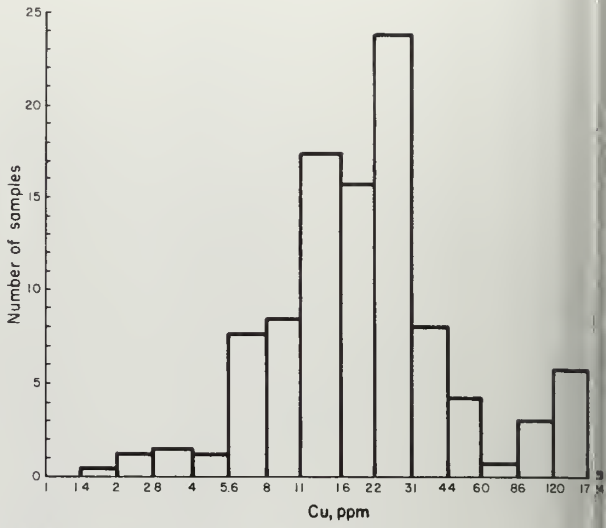


Figure 55. Histogram for copper in bedrocks.

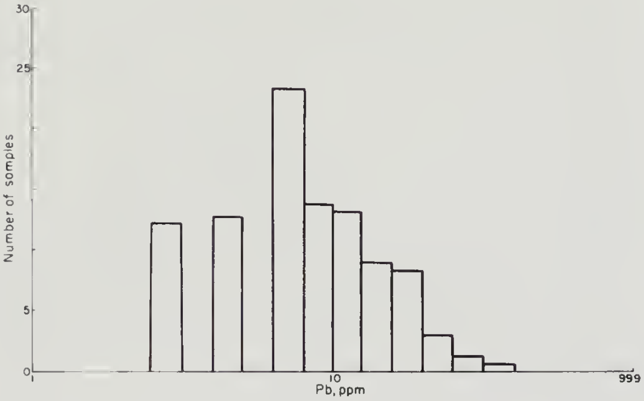


Figure 56. Histogram for lead in stream sediments.

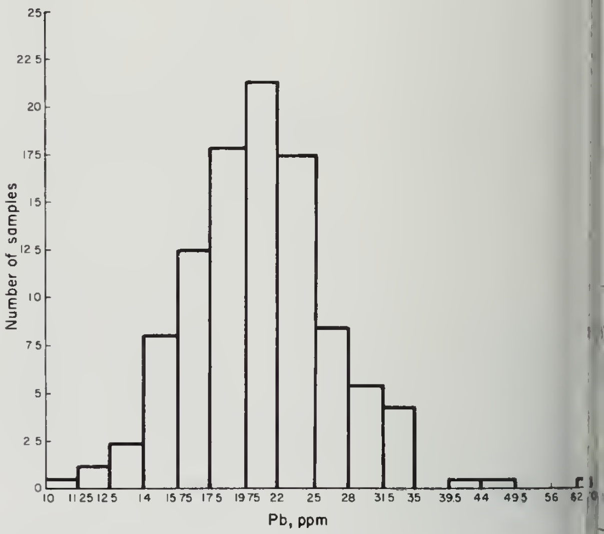


Figure 57. Histogram for lead in bedrocks.

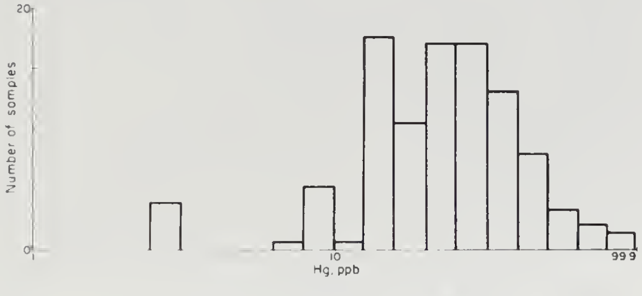


Figure 58. Histogram for mercury in stream sediments.

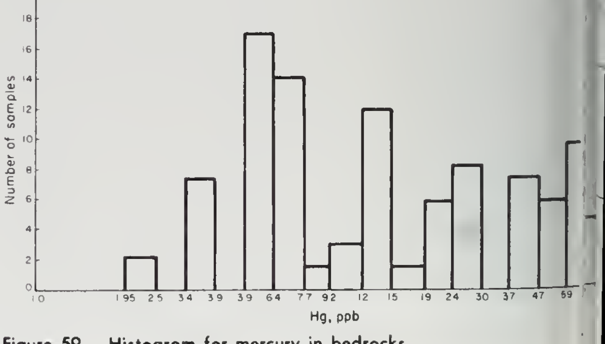


Figure 59. Histogram for mercury in bedrocks.

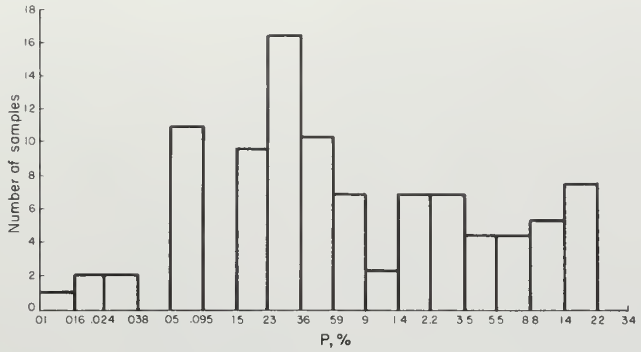
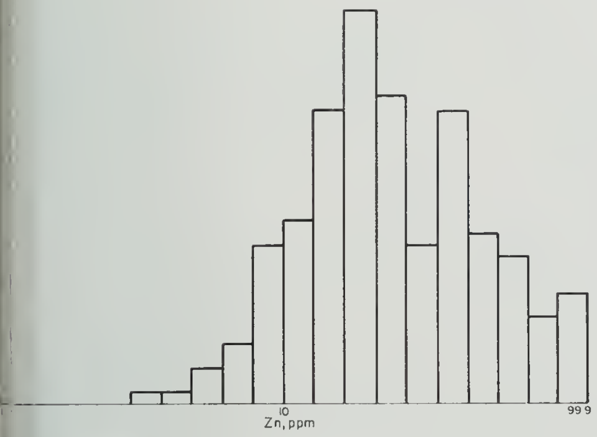


Figure 60. Histogram for phosphorus in bedrocks.



gure 61. Histogram for zinc in stream sediments.

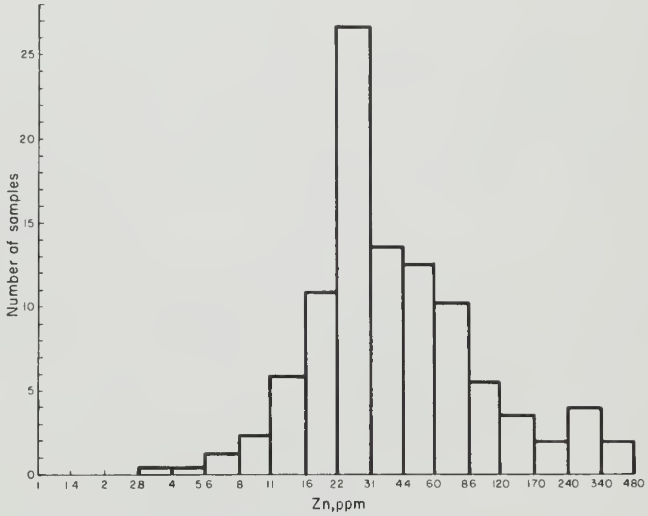


Figure 62. Histogram for zinc in bedrocks.

abl 11. Various parameters calculated on the basis of cumulative frequency curves.

arameters	As (ppm)		Cd (ppm)		Cu (ppm)		Pb (ppm)		Hg (ppb)		P* (%)	Zn (ppm)	
	Stream Sediments	Bedrocks	Stream Sediments	Bedrocks	Stream Sediments	Bedrocks	Stream Sediments	Bedrocks	Stream Sediments	Bedrocks	Bedrocks	Stream Sediments	Bedrocks
hold Level (t)	9.25	38.0	1.5	15.0	13.0	40.0	29.0	33.0	64.5	50.0	1.00	74.0	250.0
etric Mean (b)	1.4	7.0	0.2	5.2	5.1	19.0	7.9	20.0	23.4	12.5	0.52	21.5	40.0
metic Mean	2.4	10.8	1.4	27.2	7.6	30.7	9.7	21.0	21.3	27.2	2.66	26.6	46.0
an	0-11.40	0-72	0-25.6	0-625	0-38	3-195	0-54	10-63	0-88	0.560	0.06-17.11	0-97	3-468
ual Abundance lor, 1964)	1.8		0.2		55.0		12.5		80.0		0.105	70.0	
ance in Soils ograder, 1959)	5.0		0.5		20.0		10.0		10.0		0.080	50.0	

ased on analyses of only 97 samples.

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